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Fate of Toxic and Nonconventional Pollutants in Wastewater Treatment Systems Within the Pulp Paper, and Paperboard Industry

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Portland, ME

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FATE OF TOXIC AND NONCONVENTIONAL POLLUTANTS IN WASTEWATER TREATMENT SYSTEMS WITHIN THE PULP, PAPER, AND PAPERBOARD INDUSTRY

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16. ABSTRACT

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Through a sampling program of primary clarifier influent, biological treatment effluent, air emissions above the aeration tanks, and dewatered sludge solids, it was the objective of the study to complete a mass balance of the pollutants under study.

Analysis of primary clarifier influent samples was by both GC and GC/MS techniques; analysis of the remaining samples was GC method alone.

In general, 50 percent of the mass of each pollutant found in the mill's raw wastewaters were accounted for in the program. The accountability of the volatile organic pollutants ranged from 27 to 55 percent. The accountability of semi-volatile pollutants ranged from 6 to 933 percent with three pollutants accounted for in excess of 100 percent.

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FOREWORD

When energy and material resources are extracted, processed, converted and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report assesses the fate of toxic and nonconventional pollutants discharged by pulp, paper, and paperboard mills. The findings of the report may be used by researchers and regulatory agencies in assessing the removal mechanisms in biological treatment for the pollutants under study.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

Field studies were undertaken to determine the fate of toxic and non-conventional pollutants present in the wastewaters discharged from the pulp, paper, and paperboard industry. A sampling and analysis program was conducted at two deink mills and a groundwood fine papers mill. Each mill employed a wastewater treatment system which included primary clarification, high rate biological treatment, secondary clarification, and combined primary/secondary sludge dewatering.

Through a sampling program of primary clarifier influent, biological treatment effluent, air emissions above the aeration tanks, and dewatered sludge solids it was the objective of the study to complete a mass balance of the pollutants under study.

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This report was submitted in fulfillment of Contract No. 68-03-2605, Work Directives No. 3, by the E.C. Jordan Co. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 1978 to June 1980, and work was completed as of June 1980.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

atm	atmosphere
BHP	horsepower (break)
BOD_5	5 day biochemical oxygen demand
°C	degree centigrade
cm/min	centimeter per minute
cfm	cubic feet per minute
COD	chemical oxygen demand
cu cm	cubic centimeter
cu m	cubic meter
d	day
DI	de-ionized
dia	diameter
DO	dissolved oxygen
ECD	electron capture detection
EPA	U.S. Environmental Protection Agency
°F	degree Farenheit
ft	feet
FID	flame ionization detection
F/M	food to microorganism ratio
gal	gallon
GC	gas chromatography
GC/MS	gas chromatography/mass spectroscopy
gm	gram
gpd	gallons per day
gpm	gallons/minute
hp	horsepower
hr	hour
in	inch
kg	kilogram
kkg	metric ton (1,000 kilograms)
l	liter
lb	pound
min	minute
ml	milliliter
mg	milligram
mgd	million gallons/day
mg/l	milligram/liter
ml/l	milliliter/liter

MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
N	normality
O_2	oxygen
$\overline{OD}$	oven dried
O&M	operation and maintenance
psig	pounds per square inch (gauge)
sec	seconds
sq m	square meters
sq cm	square centimeters
SV/AN	semivolatile acid-neutral
SVI	Sludge Volume Index
SWD	side water depth
tpd	ton per day
ug/l	micrograms/liter

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SECTION 1

INTRODUCTION

PROGRAM OBJECTIVES

Under Work Directive No. 3 the fate of the toxic and nonconventional pollutants present in the wastewaters discharged by the pulp, paper, and paperboard industry was to be determined. As specified by the Agency the E.C. Jordan Co. was to sample "bottom sediments, air emissions and wastewater input and output for biological treatment systems treating unbleached kraft - hardwood and softwood, bleached groundwood integrated pulp mills and for NSSC only pulp mills." These biological or physical-biological treatment systems were to be sampled for toxic pollutants and other chemicals directed by the Agency but including those toxic pollutants detected during the EPA Effluent Guidelines Divisions' Best Available Technology Economically Achievable (BAT) Review Program.

Due to budgetary limitations the E.C. Jordan Co. initially recommended that only semivolatile acid-neutral compounds (SV-AN) be studied in Work Directive No. 3. This recommendation was made since available data indicated that the volatile organics were removed by aeration and benzidine was the only basic semivolatile organic detected previously in pulp, paper, and paperboard mill wastewaters. In the final formulation of the work program it was recommended that the raw wastewater samples be screened by gas chromatograph/mass spectrometry for all volatile and acid-neutral semivolatile organic pollutants previously under study in the Agency's BAT Review Program. The compounds under investigation are presented in Table 1.

Based on information gathered during the Effluent Guideline Divisions' study, the Jordan Company recommended that the subcategory selection be modified to include the following:

1. Bleached kraft,
2. Unbleached kraft (softwood),
3. Bleached groundwood, and
4. Deink.

The above recommendations were made because the wastewaters from these subcategories were known to normally contain, among others, measurable quantities of the toxic and nonconventional organic pollutants of concern.

TABLE 1. TOXIC AND NONCONVENTIONAL POLLUTANTS IN THE PULP, PAPER, AND PAPERBOARD INDUSTRY

Toxic Pollutants

Volatile Organics
- benzene
- bromoform
- carbon tetrachloride
- chlorobenzene
- chloroform
- dibromochloromethane
- dichlorobromomethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- ethylbenzene
- methylene chloride
- 1,1,2,2-tetrachloroethane
- tetrachloroethylene
- toluene
- 1,1,1-trichloroethane
- trichloroethylene
- trichlorofluoromethane
- xylene

Semivolatile Organics
- acenaphthene
- acenaphthylene
- anthracene
- bis(2-ethylhexyl)phthalate
- butyl benzyl phthalate
- 2-chlorophenol
- chrysene
- 2,4-dichlorophenol
- diethyl phthalate
- di-n-butyl phthalate
- 2,4-dinitrophenol
- di-n-octyl-phthalate
- fluoranthene
- isophorone
- naphthalene
- p-chloro-m-cresol
- pentachlorophenol
- phenol
- pyrene
- 2,4,6-trichlorophenol

Nonconventional Pollutants

Resin acids
- abietic acid
- dehydroabietic acid
- isopimaric acid
- pimaric acid

Fatty acids
- oleic acid

Bleach plant derivatives
- dichlorodehydroabietic acid
- monochlorodehydroabietic acid
- 3,4,5-trichloroguaiacol
- tetrachloroguaiacol

The E.C. Jordan Co. also recommended that only mills employing the conventional activated sludge process for wastewater treatment be considered in the response to the work directive. Aerated stabilization basin systems were deemed unacceptable, because mass balances associated with suspended solids in the treatment system could not readily be addressed as a result of the material partially settling out in the system's aeration basins. Pure oxygen activated sludge systems were also deemed inappropriate for investigation because of the enhanced probability of molecular oxidation of the subject pollutants by contact with high concentrations of pure oxygen.

Eight mills in the aforementioned four recommended subcategories were contacted by the E.C. Jordan Co. and asked to participate in the program. Of the eight mills contacted, favorable replies were received from three deink fine paper mills and three groundwood fine paper mills. The remaining two mills did not desire to participate in the program. Of the six favorable responses three mills were selected to participate in the program. Several of the responding mill personnel, in responding to the E.C. Jordan Co.'s request to participate, noted that, due to the level of pollutants present and process variations, a complete "pollutant closure" would be difficult. However the personnel felt that useful data would be gathered relative to the toxic and non-conventional pollutants. The mills participating in the program are indicated below:

Subcategory	Mill Name and Location
Deink	Bergstrom Paper Company Neenah, WI
Deink	Wisconsin Tissue Mills, Inc. Menasha, WI
Groundwood-bleached	St. Regis Paper Company Sartell, MN

To accomplish the goal of the work directive, a sampling and analysis program was developed which would allow for the calculation of pollutant mass balances across the three wastewater treatment systems investigated. Each system included primary clarification, high rate biological treatment, secondary clarification, and combined primary/secondary sludge dewatering.

Prior to finalizing the sampling and analysis program, the E.C. Jordan Co. reviewed with Agency representatives the pollutants of potential concern in the pulp, paper, and paperboard industry. It was decided that raw wastewaters would be screened by GC/MS for all of the pollutants (see Table 1). The air, sludge, and final effluent samples would be analyzed by GC for those pollutants detected in the raw wastewater by GC/MS procedures.

The program utilized in this study involved the collection of samples from the following locations at each of the three facilities investigated:

1. primary clarifier influent;

2. secondary clarifier effluent;

3. air emissions above the aeration tanks; and

4. dewatered sludge solids.

Analysis of primary clarifier influent samples was by both GC and GC/MS techniques; analysis of the remaining samples was by the GC method alone.

ORIGIN OF SPECIFIC TOXIC COMPOUNDS

Specific toxic compounds in the raw materials and the wastewaters from various mills in the pulp, paper, and paperboard industry and the wood products have been reported in the literature. Most of the literature, however, has dealt with the toxicity of various resinous and fatty acids (see Table 1).

A study by Walden found that resin acids contribute substantially to the toxicity of wastewaters from all pulping processes (1). In a similar study, Swan summarized the resin and fatty acid contents of major wood species used in the industry (2). His results, summarized in Table 2, show that pines have by far the highest acid content of species studied.

TABLE 2. TYPICAL RESIN AND FATTY ACID CONTENTS OF RAW WOOD TYPES

Species	Total resin acids (Percent by weight oven dried wood)	Total fatty acids (Percent by weight oven dried wood)
Pines	1.5%	1.0%
Other softwoods	0.1%	0.1%
Hardwoods	negligible	0.5%

The content of total resin acids was also observed to vary within the major species groups. One study showed a substantial variation in resin acid content for trees of different ages (3). It was shown also that resin acid content was a function of tree diameter; i.e., the larger the diameter, the higher the resin acid content.

Also of concern are heavy metals. These primarily originate from pigments added in paper coating and glazing operations. There is a lack of literature on specific toxicity of additives used in various papermaking operations.

Detergents used for deinking of wastepaper also contribute to toxicity. Martin determined that several such detergents were lethal to fish at a concentration of 4.0 mg/l (4). Polychlorinated biphenyls (PCB), formerly used in the manufacture of carbonless copy paper and printing inks, remain in some wastepaper mill effluents because of wastepaper recycling. The New York State Department of Conservation conducted a study concerning PCB's in wastepaper mill effluents (5). Of the 40 New York mills using wastepaper, 18 were determined to be potential direct dischargers of PCB's. Final effluent samples from these mills were analyzed monthly from October 1976 to September 1978. The results of this study indicated that final effluent PCB concentrations were generally below one microgram/liter (ug/l) and that the concentration was reduced by biological treatment.

SECTION II

CONCLUSIONS AND RECOMMENDATIONS

The objective of the program was to determine the fate of a number of toxic and nonconventional pollutants normally present in pulp, paper and paperboard wastewaters. Through a detailed sampling program of influent and effluent wastewaters, air emissions, and solid waste, it was the objective to complete a mass balance of the pollutants.

In general, 50 percent of the mass of each pollutant found in the mill's raw wastewaters were accounted for in the program. The accountability of the volatile organic pollutants ranged from 27 to 55 percent. The accountability of semivolatile pollutants ranged from 6 to 933 percent with three pollutants accounted for in excess of 100 percent.

Based on the accountability of pollutants experienced in the program, it is apparent that the objective was not achieved due to several factors. These factors include:

1. biochemical transformation;
2. laboratory analysis;
    a. quantity of pollutants,
    b. detection limits,
    c. sample matrix, and
    d. analytical procedures;
3. sampling procedures; and
4. capability to accurately estimate air and sludge emissions.

The impact of several of the factors encountered in this program may be minimized with continued research and controlled conditions.

Future studies of the fate of toxic and nonconventional pollutants in industrial wastewaters should strive for improved accountability of pollutants under study. It is unrealistic to anticipate 100 percent account-

ability, however, through more controlled conditions, more advanced sampling techniques, and higher resolution analytical techniques, improved accountability should be a realistic goal.

Sampling procedures in future programs should consider flow proportional aliquots (wastewater), composite or individual samples of sludge (solids), and a more efficient air emission sampler (air).

A statistical design of the sampling program should be considered for future programs. Through consideration of known variables, the sample sites, frequency and number of samples could be considered so that the results will have a known reliability.

SECTION III

FIELD STUDY PROGRAM

SAMPLING PROGRAM

At each of the three mills surveyed, the following were sampled:

1. Primary clarifier influent,
2. Secondary clarifier effluent,
3. Air emissions, and
4. Combined primary and secondary dewatered sludge.

Composite primary clarifier influent and secondary clarifier effluent samples were obtained by utilizing automatic samplers which collected 200 ml aliquots of the wastewater every 30 minutes for 24 hours. The composite samples were subsequently analyzed for semi-volatile organics and PCBs. Grab samples of these same waste streams were also collected and analyzed for volatile organics. Sample blanks were collected to evaluate the possibility of field or laboratory contamination.

Air samples from above the aeration tanks were collected with equipment developed by the E.C. Jordan Co. This equipment is depicted on Figure 1. Utilizing the air pump, air samples are drawn through the silicone tubing and into the alkaline scrubber which removes the semi-volatile organics and PCBs from the air stream. The partially cleansed air sample then passed through the cryogenic trap which condenses the volatile organics present. The contents of the alkaline trap were subsequently analyzed for semivolatile organics and PCBs; the contents of the cryogenic trap for volatile organics.

Daily grab samples of dewatered sludge solids were collected, placed in plastic bags, sealed, and immersed in liquid nitrogen to inhibit bacterial decomposition.

It should be noted that the composite samples were iced during collection, as well as during shipment to the analytical laboratories utilized in this study. An express air transport service was used to assure expedient delivery of all samples to the laboratories. Upon receipt of the iced shipping containers at the laboratories, the samples were extracted and analyzed. Sample blanks collected throughout the program at each sampling location were handled in an identical manner.

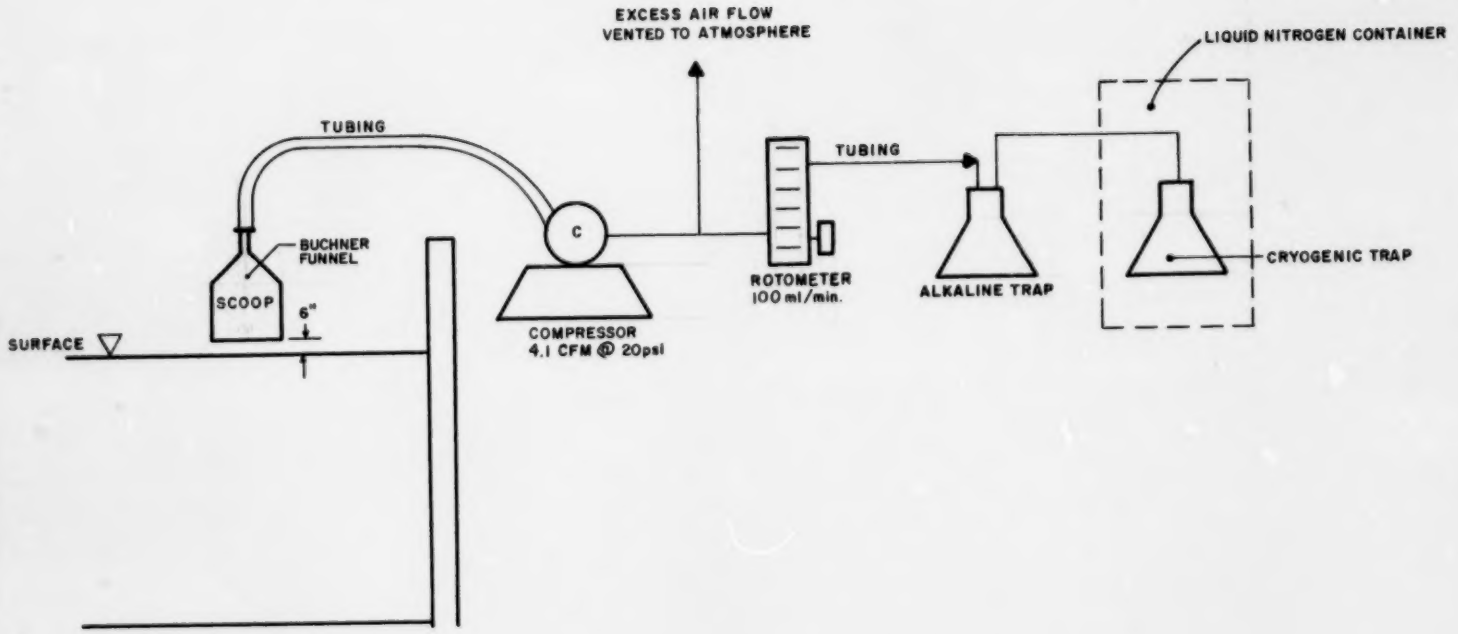

FIGURE 1. AIR SAMPLING SYSTEM

BERGSTROM PAPER COMPANY

Project Background

Mill process description. The Bergstrom Paper Company mill located in Neenah, Wisconsin has been greatly modified and expanded since its construction in 1875. Today, the mill produces approximately 295 thousand kilograms (kkg)/day of printing paper, 75-percent of which is uncoated (6).

The mill's raw materials include wastepaper (mostly bond and ledger), purchased baled pulp, broke, groundwood and pulp substitutes. Wastepaper is fed to a hydrapulper where deink chemicals are added; the stock is then processed, screened, cleaned and bleached in a CEH bleaching sequence (6). The pH of the wastewater from this process is generally alkaline in nature. Purchased pulp is repulped in additional hydrapulpers and combined with the deink stock. Various grades of printing and writing papers are made from this combined stock on three paper machines. All three machines have savealls for fiber recovery. Saveall effluent is reused as much as possible in the preparation of the deink stock. The mill operates 24 hours per day, approximately 360 days per year.

Primary wastewater treatment was initiated in 1968; biological treatment in 1976.

Water and wastewater sources and treatment. Raw water is taken from the Fox River, treated and used as the mill process water. Wastewater from the mills operations are collected and first subjected to primary clarification. Some of the primary clarifier effluent, approximately 35 percent, is also recycled to the deinking area for reuse. The remainder is subjected to biological treatment in a two-stage activated sludge system. Detailed design criteria for this system are presented in Appendix A. The entire treatment system is shown graphically on Figure 2. A general description of each unit process is presented in the following paragraphs.

The process wastewater from the mill is collected in four sewers (machine whitewater, pulp preparation, deink and bleach plant) and flows by gravity through a manually-cleaned bar screen to a wet well. In the wet well, water treatment plant backwash water and sludge press filtrate are introduced and the total flow is pumped to a primary clarifier. A polymer is added to the pump discharge to aid in the primary floculation/clarification process. As described earlier, the Bergstrom mill reuses a portion of the primary effluent in the deinking process, usually between 5,300 and 6,100 cu m/day. After removal of this volume, the remaining primary effluent volume enters a rapid mix or blend tank. In this blend tank, the pH of the wastewater is neutralized by metering concentrated sulphuric acid at a controlled rate. Sulfur dioxide can also be added at this point to destroy any residual chlorine remaining in the wastewater. Nutrients in the form of dilute phoshoric acid and ammonia are added to the blend tank effluent. Approximately 15,100 to 17,000 cu m/day of primary effluent is directed to the biological treatment system. The biological system has been designed to operate as a two-stage activated sludge system. The process consists of an initial aeration tank and secondary clarifier (first stage) followed by a

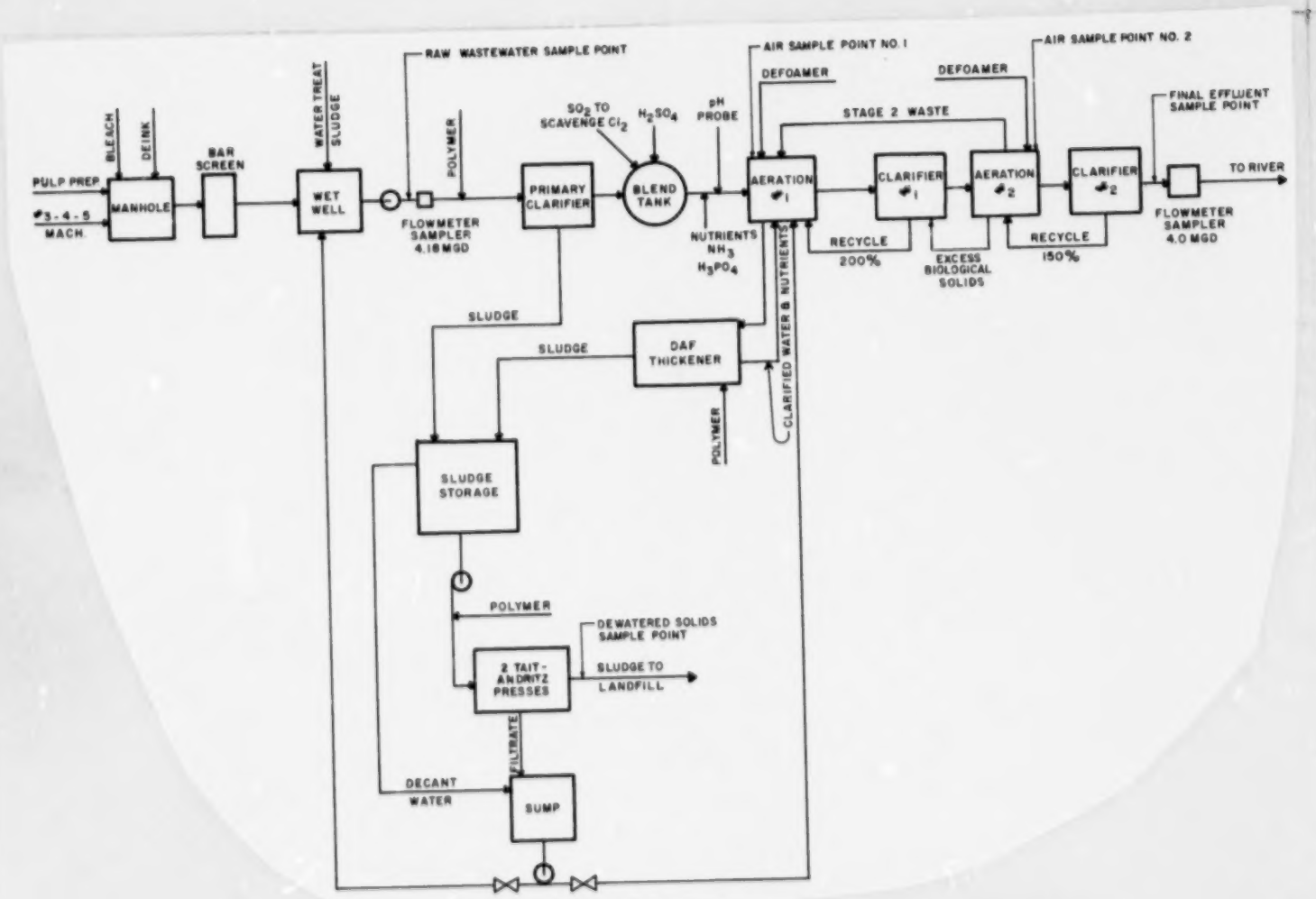

FIGURE 2. WASTEWATER TREATMENT SCHEMATIC AND SAMPLE POINTS AT BERGSTROM PAPER COMPANY

second aeration tank and final secondary clarifier (second stage). The first stage operates at a high organic loading rate (food to microorganism [F/M] ratios from 0.6 to 1.0) and short, 2 to 3 hours, detention time. The second stage operates at loading rates which would normally be considered typical of a conventional activated sludge system. F/M ratios range from 0.2 to 0.3; mixed liquor suspended solids (MLSS) concentrations average 3,000 mg/l; and detention time in the second stage aeration tank averages 4 to 6 hours. Excess biological solids in this stage are removed from the second stage aeration tank and pumped to the first stage aeration tank. Treated effluent is discharged to the Fox River.

Excess biological solids from the biological system are removed from the first stage aeration tank and pumped to a dissolved air flotation unit for thickening. Underflow from the flotation unit is directed back to the first stage aeration tank. Thickened waste activated sludge is discharged to a storage tank, and mixed with the primary sludge. A polymer is added as a conditioner, and the blended sludge is dewatered on two horizontal belt presses to an average consistency of 35 percent solids. The filtrate is returned to the influent wet well. During the survey approximately 63.5 kkg/day of sludge was disposed of in a landfill. Of the 63.5 kkg/day it was reported that 4.5 to 9.0 kkg/day of the total was biological solids while the remaining was primary sludge solids.

The following table presents a summary of the effluent quality monitored in the final discharge during the survey period, as well as for the previous eight months of 1979.

TABLE 3. BERGSTROM PAPER CO. EFFLUENT DATA COMPARISON

Parameter	Flow (cu m/kkg)	BOD5 (kg/day)	BOD5 (kg/kkg)	TSS (kg/day)	TSS (kg/kkg)
Average data Jan. to Aug. 1979	57.7	719.1	2.4	1456.0	4.9
Fate of toxicants survey	52.6	299.6	1.0	669.2	2.3
NPDES license	-	2181.0	7.4	3013.7	10.2

Comparison of the data presented in Table 3 with the Wisconsin NPDES permit conditions shows that the mill discharge is of a higher quality than the license requirements.

Field Program Summary

E.C. Jordan Co. representatives arrived at the Bergstrom mill on September 10, 1979, met with mill officials to review the program objectives, and began setting up the sampling systems. Actual sampling began on September 11 and continued until September 20. During this period, eight sets of daily composite and grab samples were taken.

The discharge force main from the wet well pumps passes through the lab and samples of raw wastewater were obtained by directing a continuous flow slip-stream (1-inch diameter hose) off the force main into a two gallon bucket. The continuous sampler was set up to withdraw aliquots from this sample bucket; grab samples, as required, were also obtained from this bucket.

Final effluent daily composite and grab samples were collected from the effluent launder of the second stage secondary clarifier. Grab samples of the dewatered sludge cake were taken daily from a conveyor that transported the dewatered cake to a temporary storage area. The sludge dewatering system operates approximately 12 hours per day, and the grab samples were usually taken halfway through this period.

Air samples were collected at two locations. From September 11 to 16, samples were taken over the first stage aeration tank. From September 17 to 20 samples were collected over the second stage aeration tank. On September 16 a liquid nitrogen leak developed in the cryogenic sample trap and the air sample could not be taken. The leak was repaired and the sampling was continued on September 17.

WISCONSIN TISSUE MILLS

Project Background

Mill process description. Wisconsin Tissue mills is located in Menasha, Wisconsin. The mill on this site was constructed in 1914, and today produces approximately 77 kkg/day of sanitary grade tissue on two paper machines (6).

The mill's raw material is primarily wastepaper, although some supplemental pulp is purchased. The raw wastepaper is first fed into a hydrapulper where deink chemicals are added, and the stock is then processed, screened, cleaned and bleached. Purchased pulp is repulped in additional hydrapulpers and combined with the deink stock.

Water and wastewater sources and treatment. Approximately 7,570 cu m/day of water is purchased from the City of Menasha Water Department and used as mill process water. Of the total water purchased, approximately 757 cu m/day is treated further and used in the mill boilers. An additional 379 cu m/day is used as cooling water. The remainder of the water is used in the deinking, pulp preparation, bleaching and tissue making areas. Approximately 7,570 to 15,140 cu m/day is discharged to the mill effluent treatment

plant. Some of the primary clarifier effluent is reused in the deinking area. The remainder is subjected to secondary treatment in a two-stage activated sludge process. Detailed design criteria for this system were not available in Wisconsin Tissue Mills. The entire treatment system is shown graphically on Figure 3. A general description of each unit process is presented in the following paragraphs.

The wastewater in the mill is collected in two sewers and combined in a mill sump. The flow is then directed through a mechanically cleaned bar screen and grit removal equipment, and on to a pump wet well. Bentonite clay can be added to the wastewater at the wetwell to aid in the primary sedimentation process. From the wetwell the wastewater is pumped to a primary clarifier. A polymer is added to aid in the flocculation/clarification process. After primary clarification, a portion of the primary treated wastewater is recirculated to the deinking area for reuse.

Nutrients in the form of dilute phosphoric acid and ammonia are added to the remaining primary effluent, as this flow is directed to a two-stage activated sludge system.

Excess biological solids generated within the secondary system, along with rejects from the deink mill are pumped at a controlled rate to a dissolved air flotation unit (DAF). Primary sludge is blended with DAF sludge and then conditioned with a polymer and dewatered on three horizontal belt filters. The filter cake is generally 30 to 35 percent solids, and is disposed of in a landfill.

Table 4 presents a summary of final effluent quality during the survey (September 12 to 20, 1979) and for the previous eight months of 1979.

TABLE 4. WISCONSIN TISSUE MILLS EFFLUENT DATA COMPARISON

Parameter	Flow (cu m/kkg)	BOD5 (kg/day)	BOD5 (kg/kkg)	TSS (kg/day)	TSS (kg/kkg)
Average data Jan. to Aug. 1979	80.0	127.6	1.7	223.4	2.9
Fate of toxicant survey	94.3	202.5	2.6	570.7	7.4
NPDES license	-	537.5	7.0	727.3	9.4

Comparison of the data presented in Table 4 to the NPDES license conditions shows that the average quality of the mill discharge has been better than the license conditions.

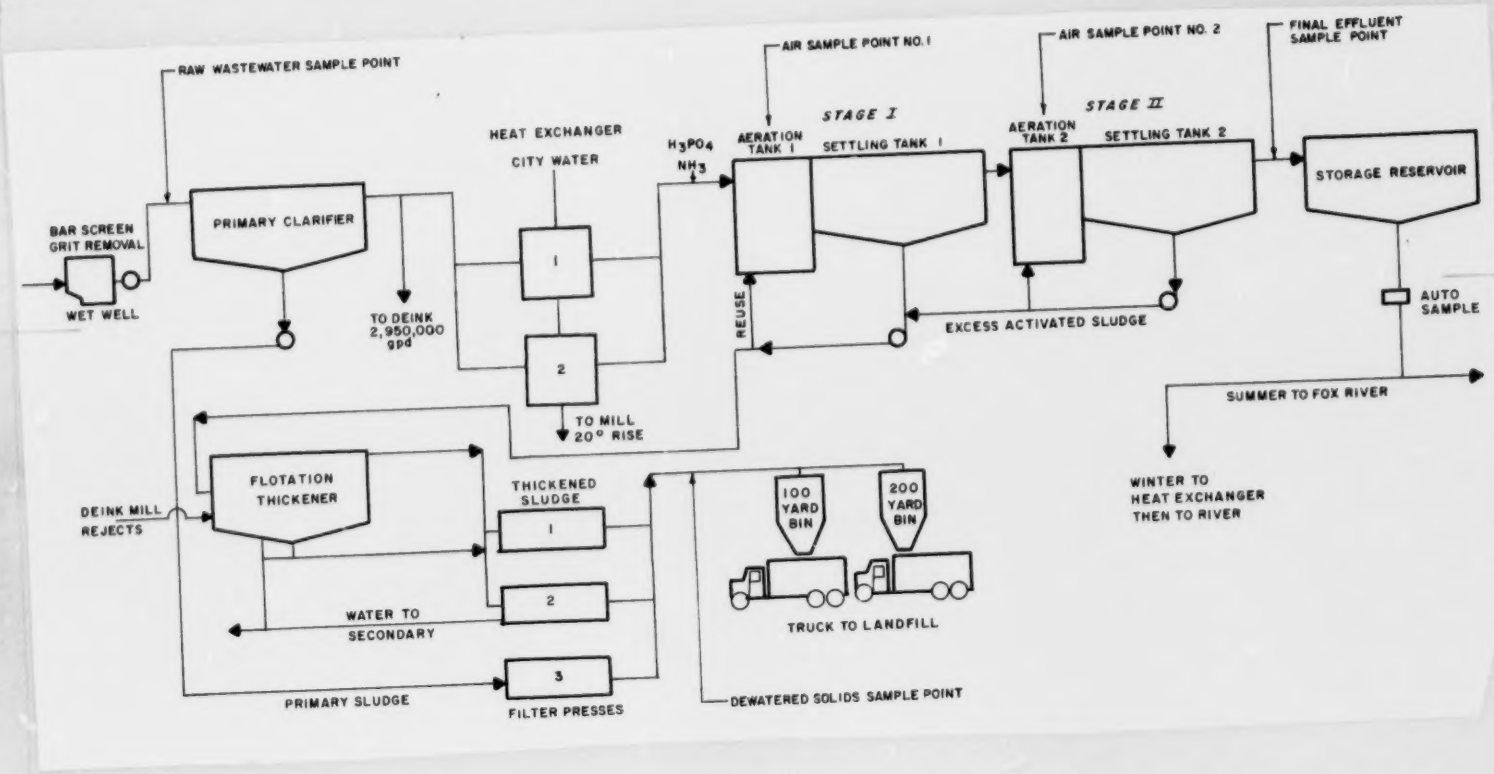

FIGURE 3. WASTEWATER TREATMENT SCHEMATIC AND SAMPLE POINTS AT WISCONSIN TISSUE MILL

Field Program Summary

The E.C. Jordan Co. personnel arrived at Wisconsin Tissue mills on September 10, 1979, and met with mill officials to review the program objectives. Sampling began on September 11 and continued until September 20. During this time, eight sets of daily composite and grab samples were taken.

The primary influent samples were taken at a location immediately downstream from the mechanically-cleaned bar screen, while the final effluent samples were collected from the effluent launder of the second stage secondary clarifier. Grab samples of the dewatered sludge cake were taken daily at random intervals, from a conveyor transporting the dewatered cake to a temporary storage area. The sludge dewatering system operates approximately 12 hours per day. The final dewatered cake is made up of 60 percent primary solids and 40 percent secondary solids. Mill officials state that the final cake average is from 30 to 35 percent solids.

Air samples were collected at two locations. From September 11th to the 16th, samples were taken over the first stage aeration tank, and from September 17th to 20th samples were collected over the secondary stage aeration tank.

ST. REGIS PAPER COMPANY

Project Background

Mill process description. The St. Regis Paper Company mill located in Sartell, Minnesota is in the groundwood fine papers subcategory of the pulp, paper, and paperboard industry and produces approximately 122 kkg/day of groundwood, mostly from softwoods. Additional baled softwood pulp is purchased. Uncoated groundwood printing and converting production from two machines averages 208 kkg/day (6).

Logs are conveyed to the loading dock, slashed and debarked. Groundwood is produced in pocket grinders. Both wet and dry debarking systems are used. The pulp passes through additional refining, bleaching and blending stages, and is processed on two machines. The mill uses a two-stage bleaching sequence of peroxide followed by sodium hydrosulfite.

Water and wastewater sources and treatment. Raw water is pumped from the Mississippi River, treated and used as process water. Boiler feedwater is drawn from the river, softened and dealkalized. Approximately 15,140 to 18,925 cu m/day of wastewater is sent to the treatment plant. Secondary treatment is provided using a high-rate activated sludge system.

The detailed design criteria for this system are presented as Appendix B of this report. The entire treatment system is shown graphically in Figure 4. A general description of each unit process is presented in the following paragraphs.

Wastewater from the mill flows by gravity to a wet well. It is then pumped to a flow splitter box, dividing the flow equally to two primary

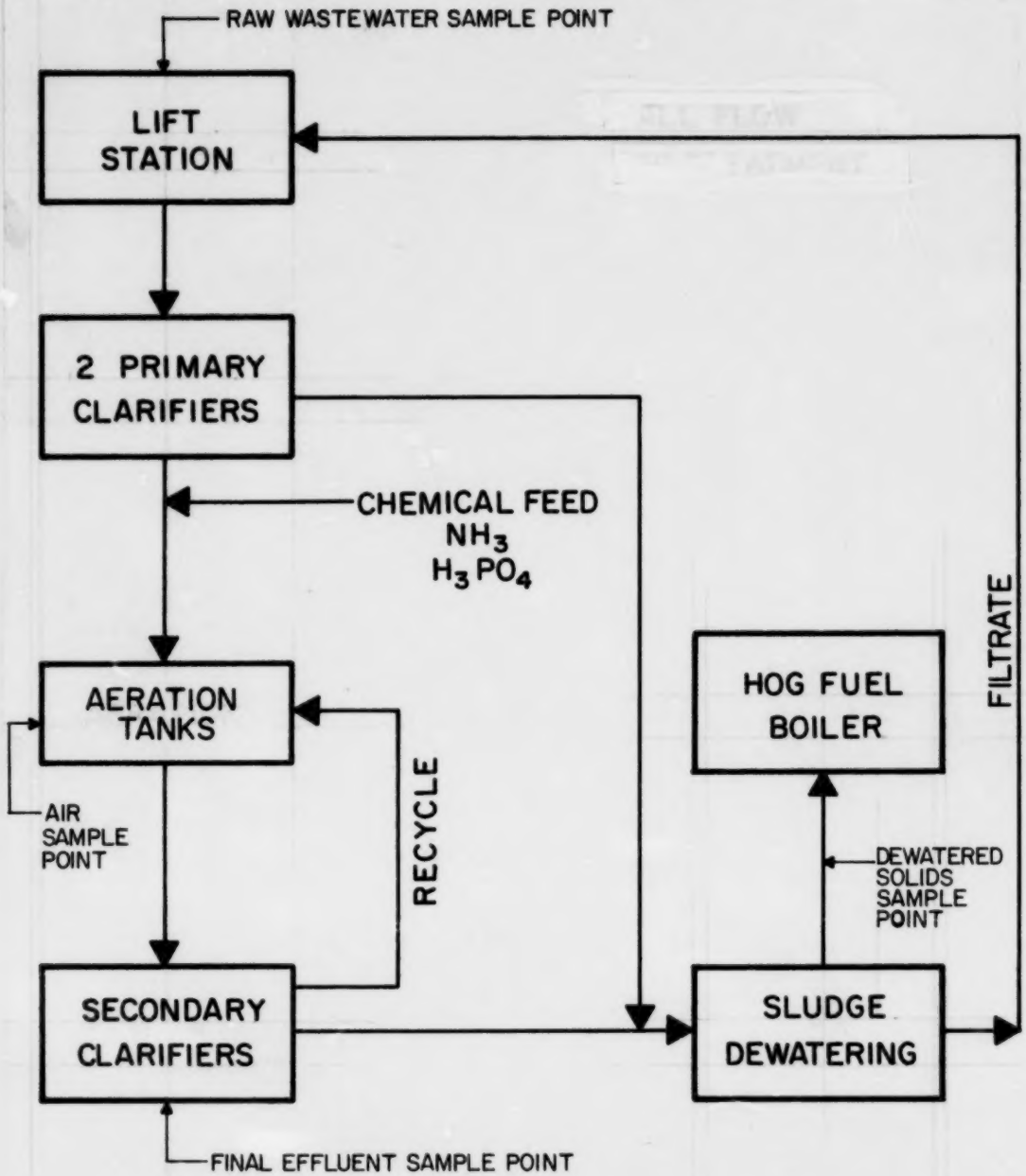

FIGURE 4. WASTEWATER TREATMENT SCHEMATIC AND SAMPLE POINTS AT ST. REGIS PAPER COMPANY

clarifiers. Nutrients in the form of dilute phosphoric acid and ammonia (BOD5:N:P ratio 100:4:2) are added to the primary clarifier effluent.

The primary effluent is divided equally between two aeration tanks and receives secondary treatment in a high-rate activated sludge system. F/M ratios within the system vary from 0.40 to 0.70. Detention time of the waste flow in the aeration tanks averages 5 to 7 hours. From the aeration tanks, the wastewater then flows to a splitter box which divides the flow equally to secondary clarifiers. Biological (activated) sludge is recycled from the secondary clarifiers to the aeration tanks. Recycle rates normally range from 25 to 40 percent of the influent flow rate.

Primary sludge and waste biological sludge are blended, dewatered by vacuum filters, then pressed in a mechanical filter. The final sludge cake is mixed with sawdust and bark and burned in a hog fuel boiler. Filtrate and pressate are collected and returned to the influent wetwell. Overall retention time in the treatment system is between 12 and 16 hours. The final effluent is discharged through a diffuser to the Mississippi River.

The performance of the St. Regis waste treatment facility is summarized in Table 5, which compares effluent quality during the survey period with mill NPDES license conditions.

TABLE 5. ST. REGIS PAPER COMPANY - EFFLUENT DATA COMPARISON

Parameter	Flow (cu m/d/kkg)	BOD5 (kg/day)	BOD5 (kg/kkg)	TSS (kg/day)	TSS (kg/kkg)
Fate of toxicants survey	71.0	104.0	0.5	272.9	1.3
NPDES license levels	-	553.9	2.7	885.3	4.3

It is evidenced in Table 5 that average effluent quality of the St. Regis facility was better than the license conditions imposed by the regulatory agency.

Field Program Summary

On arrival at the St. Regis mill on October 5, 1979, the Jordan Company personnel reviewed with mill personnel the program objectives. The sampling systems were set up, and operated from October 8 through October 13. During this period, five sets of daily composite and grab samples were taken.

The raw wastewater samples were collected in the headworks area of the plant, immediately downstream from a mechanically-cleaned bar screen. Final

effluent samples were collected immediately upstream from the final effluent flow monitoring station.

The dewatered sludge grab samples were taken at the discharge end of the coil filter. Samples were taken at random intervals each day, normally between 8 a.m. and noon. The dewatering system operates between 12 and 16 hours a day, and mill officials report that the average percent solids in the filter cake ranges between 18 and 25 percent.

All composite air samples were collected over the aeration tank. Blank air samples were collected in an area adjacent to the treatment plant site. Four separate sets of air and blank samples were collected during the survey.

SECTION IV

LABORATORY PROGRAM

INTRODUCTION

Selection of Dominant Pollutants

Upon completion of each day's field efforts, samples of the air trap, dewatered sludge, secondary sludge and final effluent were sent to the Jordan Company laboratory and the raw wastewater composite was sent to the laboratory of the Gulf South Research Institute (GSRI), New Orleans, LA. The GSRI laboratory extracted the sample, and analyzed by GC/MS analytical techniques for toxic and nonconventional organic pollutants. An aliquot of the raw wastewater extractant was sent to the Jordan laboratory. A pollutant was considered to be present if a concentration of 10 µg/l or greater was measured. E.C. Jordan Co. analysis of all samples, including the raw wastewater samples, for the toxic and nonconventional organic pollutants utilized GC techniques, alone. Table 6 summarizes the parameters detected by both analytical techniques.

TABLE 6. SUMMARY OF POLLUTANTS DETECTED IN GREATER THAN 10 MICROGRAMS/LITER

Parameter	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
Volatile Organics			
chloroform	Yes	Yes	Yes
dichlorobromomethane	Yes	No	No
1,1,1-trichloroethylene	Yes	No	No
trichloroethylene	Yes	No	No
Semi-Volatile Organics			
2,4-dichlorophenol	Yes	No	No
2,4,6-trichlorophenol	Yes	No	No
di-n-butyl phthalate	No	Yes	No
bis(2-ethylhexyl)phthalate	No	Yes	No
naphthalene	Yes	Yes	Yes

TABLE 6 (Continued)

Parameter	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
oleic acid	Yes	Yes	Yes
linoleic acid	Yes	Yes	Yes
pimaric acid	Yes	Yes	Yes
isopimaric acid	Yes	Yes	Yes
dehydroabietic acid	Yes	Yes	Yes
abietic acid	Yes	Yes	Yes
trichloroguaiacol	Yes	No	No
tetrachloroguaiacol	Yes	No	No
monochlorodehydroabietic acid	Yes	Yes	No
Others			
cyanide	Yes	Yes	NA*
PCB's	Yes	Yes	NA*

*NA - Not analyzed.

It should be noted that 1,1,1-trichloroethylene, dichlorobromomethane, trichloroethylene, and naphthalene were detected in the wastewaters from Bergstrom Paper Company alone and that linoleic acid appeared in the raw wastewaters from all three mills. Based on data developed in the Effluent Guidelines Division studies these compounds are not usually encountered. Conversely, pentachlorophenol, dichlorodehydroabietic acid, and anthracene are normally present in mill raw wastewaters; however, their presence was not detected in the the three mills surveyed.

INSTRUMENTATION AND CHEMICALS

Volatile and semi-volatile organics and PCB analyses were undertaken in the E.C. Jordan Co. laboratory using a Perkin-Elmer Sigma 1 GC and in the GSRI laboratory using a Hewlett-Packard Model 5985 GC/MS.

Nanograde solvents from a single lot were purchased at the beginning of the project and utilized by both laboratories for sample extractions and subsequent analyses. Resinous and fatty acid, as well as chlorinated guaiacol standards, were provided by the National Council for Air and Stream Improvement of the Pulp and Paper Industry, Inc. (NCASI) of Corvallis, OR. Volatile organic standards were obtained from Analabs of North Haven, CT. Chromatographic grade N-methyl-N'-nitro-N-nitrosoguanidine, used in the preparation of diazomethane, was purchased from Aldrich Chemical Company of Milwaukee, WI.

ANALYTICAL PROCEDURES

Analytical procedures utilized by the GSRI laboratory for the organic analysis of raw wastewater samples by GC/MS techniques have been outlined in a separate report to the Jordan Company (7).

Analytical procedures utilized by the Jordan Company for volatile and semi-volatile organics and for PCB's were in accordance with EPA protocol (8). For resinous and fatty acids, the analytical procedures developed by the NCASI were utilized (9).

Analytical procedures for sludge samples developed by the EPA Office of Research and Development (R&D), Midwest Research Institute (MRI), and Battelle (10)(11).

QUALITY CONTROL/QUALITY ASSURANCE (QC/QA)

The GC system was inspected prior to the analysis of each sample set. Included in the analysis of each sample set was the inclusion of composite standards which contained all compounds of interest in the study. Concentration versus linearity of response studies were undertaken for selected compounds present in the wastewaters analyzed. The summary results of these studies are presented in Table 7.

TABLE 7. CONCENTRATION/RESPONSE LINEARITY RESULTS

Compound	Area Counts/Nanogram	
	Average	Standard Deviation
2,4,6-trichlorophenol	0.230	0.018
2,4-dichlorophenol	0.266	0.035
linoleic acid	0.399	0.044
abietic acid	0.246	0.020
heptadecanoic acid	0.313	0.022

Approximately 10 percent of all samples were subjected to duplicate analysis. These are presented with the raw data in Appendix D. In addition to the above, spike recovery studies were undertaken using the organic compound, heptadecanoic acid. Heptadecanoic acid is an odd-carbon fatty acid which does not occur naturally. Therefore, it was selected as a surrogate compound for the resin and fatty acids studied.

This effort is summarized in Table 8.

TABLE 8. HEPTADECANOIC ACID RECOVERY RESULTS, PERCENT

Mill	Type of Sample		
	Cryogenic	Dewatered Sludge	Final Effluent
Bergstrom Paper Co.	60	137	103
Wisconsin Tissue Mills	58	640	107
St. Regis Paper Co.	63	48	77

As can be seen, varying percent recovery of heptadecanoic acid are reported. Fairly consistent results are reported for the cryogenic and final effluent samples, while the dewatered sludge recoveries were inconclusive. Several factors are suspected as contributing to the variations in recovery. The factors are as follows:

1. complexity of sample matrix;

2. sensitivity of analysis; and

3. applicability of analysis for fatty and resin acids.

SECTION V

PRESENTATION OF RESULTS

GENERAL

The objective of the efforts associated with Work Directive No. 3 was to determine the fate of various toxic and nonconventional pollutants during the combined primary and biological treatment of wastewaters from two deink and one groundwood mills.

The average concentrations of those pollutants detected in the raw wastewater, final effluent, sludge solids, and air emissions for each of the three mills are given in Tables 9, 10, 11, and 12, respectively. Individual daily concentration data are presented in Appendix D.

The E.C. Jordan Co. utilized GC techniques while GSRI utilized GC/MS techniques. As anticipated, there were variations between the analytical techniques. The higher values obtained by the packed column GC technique as compared with GC/MS were predictable due to possible saturation of the mass spectrometer, in some instances, inability to resolve isomers of resin acids and other co-eluting interferences. To normalize all data, results obtained by the two techniques were averaged and factors between the GC/MS and average value, as well as GC and average values, were established. These factors were then applied to data derived from only one analytical technique to obtain the desired normalized data. An example of this normalization procedure is presented in Appendix E, as well as the actual values which served as the basis for the normalization procedure.

The normalized concentrations of the organic pollutants detected were also combined with the flow rates measured (or calculated) at each sampling point to allow for the calculation of the pollutant mass present at each point in the three wastewater treatment plants surveyed. Summaries of these mass balance data for the three mills are presented in Tables 13, 14, and 15.

INTERPRETATION OF RESULTS

The mass balance data presented indicates erratic accountability for the organic pollutants present in the raw wastewater from the three mills surveyed as they were subjected to primary and biological treatment. These results are summarized in Table 16.

TABLE 9. RAW WASTEWATER AVERAGE CONCENTRATION OF POLLUTANTS

Pollutant Name	EPA No.	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
Volatiles				
1,1,1-trichloroethane	11	42	-	-
chloroform	23	4,200	460	19
dichlorobromomethane#	48			
trichloroethylene#	87	870	-	-
Semi-Volatiles				
2,4,6-trichlorophenol	21	59	-	-
2,4-dichlorophenol	31	20	-	-
naphthalene	55	260	-	-
bis(2 ethylhexyl)phthalate	66	-	68	-
di-N-butyl phthalate	68	-	260	-
abietic acid	130	55	1,700	290
dehydroabietic acid	131	3,900	4,700	110
isopimaric acid	132	240	610	90
pimaric acid	133	59	220	60
oleic acid	134	830	480	140
linoleic acid	135	360	150	73
monochloro dehydroabietic acid	139	230	1,300	-
3,4,5-trichloroguaiacol	141	6	-	-
tetrachloroguaiacol	142	8	-	-
Others				
PCB - 1254	107	9	-	*
PCB - 1016	112	26	34	*

NOTES:

1. All results expressed as ug/l.
2. (*) PCB analysis not performed.
3. (-) compound not detected.
4. (#) compounds coelute.

TABLE 10. FINAL EFFLUENT AVERAGE CONCENTRATION OF POLLUTANTS

Pollutant Name	EPA No.	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
Volatiles				
1,1,1-trichloroethane	11	12	-	-
chloroform	23	66	43	10
dichlorobromomethane#	48			
trichloroethylene#	87	9	-	-
Semi-Volatiles				
2,4,6-trichlorophenol	21	81	-	-
2,4-dichlorophenol	31	18	-	-
naphthalene	55	10	-	-
bis(2 ethylhexyl)phthalate	66	6	5	-
di-N-butyl phthalate	68	6	5	-
abietic acid	130	6	19	12
dehydroabietic acid	131	35	38	5
isopimaric acid	132	6	6	3
pimaric acid	133	5	5	33
oleic acid	134	21	40	79
Linoleic acid	135	4	4	35
monochloro dehydroabietic acid	139	57	140	-
3,4,5-trichloroguaiacol	141	37	-	-
tetrachloroguaiacol	142	28	-	-
Others				
PCB - 1254	107	0.1	-	*
PCB - 1016	112	0.1	0.05	*

NOTES:

1. All results expressed as ug/l.
2. (*) PCB analysis not performed.
3. (-) compound not detected.
4. (#) compounds coelute.

TABLE 11. DEWATERED SLUDGE AVERAGE CONCENTRATION OF POLLUTANTS

Pollutant Name	EPA No.	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
Volatiles				
1,1,1-trichloroethane	11	*	*	*
chloroform	23	*	*	*
dichlorobromomethane#	48	*	*	*
trichloroethylene#	87	*	*	*
Semi-Volatiles				
2,4,6-trichlorophenol	21	140	-	-
2,4-dichlorophenol	31	150	-	-
naphthalene	55	430	-	-
bis(2 ethylhexyl)phthalate	66	-	16,000	-
di-N-butyl phthalate	68	-	460	-
abietic acid	130	4,050	1,830	8,520
dehydroabietic acid	131	2,000	300	15,000
isopimaric acid	132	4,200	2,400	6,400
pimaric acid	133	2,200	540	540
oleic acid	134	2,300	1,300	1,600
linoleic acid	135	430	470	430
monochloro dehydroabietic acid	139	1,100	5,700	-
3,4,5-trichloroguaiacol	141	120	-	-
tetrachloroguaiacol	142	120	-	-
Others				
PCB - 1254	107	650	-	*
PCB - 1016	112	520	540	*

NOTES:

1. All results expressed as ug/kg of dewatered sludge.
2. (*) Analysis not performed.
3. (-) compound not detected.
4. (#) compounds coelute.

TABLE 12. AIR SAMPLES AVERAGE CONCENTRATION OF POLLUTANTS

Pollutant Name	EPA No.	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
Volatiles				
1,1,1-trichloroethane	11	1.3/0.9	-	-
chloroform	23	4.4/3.6	4/3	0.40
dichlorobromomethane	48			
trichloroethylene	87	0.2/1.3	-	-
Semi-Volatiles				
2,4,6-trichlorophenol	21	-	-	-
2,4-dichlorophenol	31	-	-	-
naphthalene	55	-	-	-
bis(2 ethylhexyl)phthalate	66	-	5/5	-
di-N-butyl phthalate	68	-	5/5	-
abietic acid	130	-	4/4	4
dehydroabietic acid	131	2/7	15/6	11
isopimaric acid	132	-	4/5	5
pimaric acid	133	-	7/4	6
oleic acid	134	-	5/6	6
linoleic acid	135	-	4/4	4
monochloro dehydroabietic acid	139	-	4/4	-
trichloroguaiacol	141	11/6	-	-
tetrachloroguaiacol	142	-	-	-
Others				
PCB - 1254	107	*	*	*
PCB - 1016	112	*	*	*

NOTES:

1. All results expressed as ug/6 liters of air.
2. (*) PCB analysis not performed.
3. (1st/2nd) indicates two aeration tanks.
4. (-) compound not detected.
5. (#) compounds coelute.

TABLE 13. BERGSTROM PAPER COMPANY
SUMMARY OF THE POLLUTANT MASS BALANCES

Pollutant Name	EPA No.	A Raw Wastewater	B Primary Sludge	(A-B)=C Primary Effluent	D Recycle Back to Mill	(C-D)=E Secondary Influent	F Secondary Sludge	G Air Emission	(E-F)-G=H	I Final Effluent	H-I Unaccounted For	Percent Accounted For
1,1,1-trichloroethane	11	1.900	-	1.900	0.490	1.4	-	.16	1.2	.39	.85	55.0
chloroform	23	190.00	-	190.00	50.00	140.00	-	.56	140.00	2.2	140.00	27.0
trichloroethylene and dichlorobromomethane	87 48	34.00	-	39.00	10.00	29.00	-	.08	29.00	.30	29.00	27.0
2,4,6-trichlorophenol	21	2.70	.06	2.6	.680	2.00	.01	-	1.9	2.7	.78	130.0
2,4-bichlorophenol	31	.91	.06	.86	.22	.64	.01	-	.63	.60	.02	97.0
naphthalene	55	12.00	.17	12.00	3.00	8.50	.02	-	8.5	.35	8.2	30.0
bis(2-ethylhexyl)phthalate	66	-	-	-	-	-	-	-	-	-	-	
di-N-butyl phthalate	68	-	-	-	-	-	-	-	-	-	-	
abietic acid	130	2.500	1.6	.93	.24	.69	.19	-	.50	.18	.31	88.0
dehydroabietic acid	131	180.0	.80	180.00	46.0	130.00	.10	.48	-	1.2	130.00	27.0
isopimaric acid	132	11.0	1.7	9.200	2.4	6.8	.20	-	6.6	.19	6.4	41.0
pimaric acid	133	2.70	.86	1.800	0.47	1.30	.10	-	1.2	.17	1.1	60.0
oleic acid	134	38.0	.91	37.00	9.5	27.0	.11	-	27.0	.72	26.00	30.0
linoleic acid	135	16.00	.17	16.000	4.20	12.00	.02	-	12.0	.14	12.00	28.0
monochloro dehydroabietic acid	139	11.00	.45	10.000	2.6	7.5	.05	-	7.5	1.9	5.6	48.0
3,4,5-trichloroguaiacol	141	.28	.05	.24	.06	.18	.01	1.3	-	1.2	2.3	930.0
tetrachloroguaiacol	142	.36	.05	.31	.08	.23	.01	-	.22	.95	.73	300.0
PCB-1254	107	.36	.26	.100	.03	.07	.03	*	.04	.00	.09	89.0
PCB-1016	112	1.2	.21	1.00	.26	.74	.02	*	.72	.00	.72	41.00

Notes: 1. Results expressed in lb/day, except as noted.
* PCB's not analyzed in air emission.
# Compounds coelute

TABLE 14. WISCONSIN TISSUE MILLS
SUMMARY OF THE POLLUTANT MASS BALANCES

Compound	Compound No.	A Raw Wastewater	B Primary Sludge	(A-B)=C Primary Effluent	D Recycle Back to Mill	(C-D)=E Secondary Influent	F Secondary Sludge	G Air Emission	(E-F)-G=H	I Final Effluent	H-I Unaccounted For	Percent Accounted For
chloroform	23	14.0	-	14.00	5.9	7.8	-	.52	7.3	.62	6.6	51.0
bis(2-ethylhexyl)phthalate	66	2.0	1.2	.75	.32	.43	.92	.68	1.2	.09	1.3	160.0
di-N-butyl phthalate	68	7.7	.03	7.7	3.3	4.4	.03	.68	3.7	.09	3.6	54.0
abietic acid	130	50.0	.14	50.00	21.0	28.0	.10	.54	28.0	.30	27.0	45.0
dehydroabietic acid	131	140.00	.02	140.00	59.0	78.0	.02	1.6	76.0	.58	76.0	45.0
isopimaric acid	132	18.00	.17	18.00	7.7	10.0	.13	.56	9.5	.09	9.4	48.0
pimaric acid	133	6.5	.04	6.4	2.8	3.7	.03	.81	2.8	.08	2.7	58.0
oleic acid	134	14	.10	14.00	6.1	8.0	.07	.69	7.4	.74	6.6	54.0
linoleic acid	135	4.7	.04	4.7	2.0	2.7	.03	.54	2.1	.07	2.0	57.0
monochloro dehydroabietic acid	139	37	.42	37.0	16.0	21.0	.32	.54	20.0	2.2	18.00	52.0
PCB-1016	112	1.00	.04	.95	.41	.54	.03	*	.51	.00	.51	48.0

Notes: 1. Results expressed in lb/day, except as noted.

TABLE 15. ST. REGIS PAPER COMPANY
SUMMARY OF THE POLLUTANT MASS BALANCES

Pollutant Name	EPA No.	A Raw Wastewater	B Primary Sludge	(A-B)=C Primary Effluent	D Recycle Back to Mill	(C-D)=E Secondary Influent	F Secondary Sludge	G Air Emission	(E-F)-G=H	I Final Effluent	H-I Unaccounted For	Percent Accounted For
chloroform	23	.63	-	.63	-	.63	-	-	.63	.32	.30	51.0
abietic acid	130	9.9	.50	9.4	-	9.4	.24	-	9.1	.41	8.7	12.0
dehydroabietic acid	131	24.0	.88	23.0	-	23.0	.43	-	23.0	.16	22.0	6.2
isopimaric acid	132	3.0	.37	2.6	-	2.6	.19	-	2.5	.10	2.4	22.0
pimaric acid	133	2.0	.03	2.0	-	2.0	.02	-	2.0	1.1	.91	55.0
oleic acid	134	4.7	.09	4.7	-	4.7	.05	-	4.6	2.6	2.0	54.0
linoleic acid	135	2.5	.03	2.4	-	2.4	.01	-	2.4	1.1	1.3	48.0

Notes: 1. Results expressed in lb/day, except as noted.
* PCB's not analyzed in air emission.

TABLE 16. PERCENT ACCOUNTABILITY OF POLLUTANTS THROUGH BIOLOGICAL TREATMENT

Pollutant Name	No.	Bergstrom Paper Co.	Wisconsin Tissue Mills	St. Regis Paper Co.
Volatiles				
1,1,1-trichloroethane	11	55.0	NP	NP
chloroform	23	27.0	51.0	51.0
dichlorobromomethane#	48	27.0	NP	NP
trichloroethylene#	87			
Semi-Volatiles				
2,4,6-trichlorophenol	21	130.0	NP	NP
2,4-dichlorophenol	31	97.0	NP	NP
naphthalene	55	30.0	NP	NP
bis(2 ethylhexyl)phthalate	66	NP	160.0	NP
di-N-butyl phthalate	68	NP	54.0	NP
abietic acid	130	88.0	45.0	12.0
dehydroabietic acid	131	27.0	45.0	6.2
isopimaric acid	132	41.0	48.0	22.0
pimaric acid	133	60.0	58.0	55.0
oleic acid	134	30.0	54.0	55.0
linoleic acid	135	28.0	57.0	48.0
monochloro dehydroabietic acid	139	48.0	52.0	NP
3,4,5-trichloroguaiacol	141	930.0	NP	NP
tetrachloroguaiacol	142	300.0	NP	NP
Others				
PCB - 1254	107	89.0	NP	NP
PCB - 1016	112	41.0	48.0	NP

Notes:

NP - Not present.
\# - Compounds coelute.

As stated in Section II, the primary objective of the program was to determine the fate of a number of toxic and nonconventional pollutants. Theoretically the pollutants being discharged in the raw wastewater should, for the most part, be accounted for in the air emissions, dewatered sludge and the final effluent. However, this theoretical objective in practice was not achieved.

The authors believe the primary factor impacting the ability to achieve the mass balance is biochemical transformation. In biological treatment, the microorganisms decompose the organic materials in the influent wastewater. In the process, biochemical transformations will occur. The extent of the biochemical transformation will depend on process design characteristics, operational factors and characteristics of the organic compounds. As an example, PCB's are bioresistant and would not be anticipated to undergo biochemical transformation. The other organics under investigation are not as bioresistant and may consequently be transformed.

In general, excluding the data with greater than 100 percent accountability, 50 percent of the pollutants were accounted for in this program. The accountability of the volatile organic pollutants ranged from 27 to 55 percent. The accountability of semi-volatile pollutants ranged from 6 to 933 percent with three pollutants accounted for in excess of 100 percent. The range for the PCB's was from 40 to 90 percent. It is therefore apparent that biochemical transformation accounts for a portion of the unaccounted for pollutants. However, since the PCB's were not completely accounted for, it is apparent that other factors may have also affected the results.

In addition to biochemical transformation, other factors additionally impact the ability to complete a mass balance. These additional factors may include:

1. laboratory analysis;
    a. quantity of pollutants,
    b. detection limits,
    c. sample matrix,
2. sampling procedures; and
3. capabilities to accurately estimate air and sludge emissions.

The pollutants under investigation are typically present at microgram per liter quantities. These concentration levels oftentimes approach detection limits of the analytical procedures. At levels approaching the detection limit, the accuracy of the analytical procedures is significantly reduced. The laboratory analysis can be further impacted by the complexity of the sample matrix. The sample matrix can affect the detection limit for a particular sample, as well as the accuracy of the analysis.

In conventional pollutant sampling programs, the sampling procedures can impact the analytical results. In organic pollutant sampling programs where the pollutants are present in microgram per liter quantities, the sampling procedures can have a more significant impact. This impact is analogous to the accuracy of the analytical procedures.

In conventional wastewater sampling programs flow measurement devices are typically a part of the effluent treatment system. Normally, accurate wastewater flow data is consequently generated for the sampling program. Sampling of other medias pose a problem which is not normally encountered in wastewater sampling. This problem is the ability to measure or estimate the quantity of emission (discharge). Solid waste or sludge generation may be estimated based upon operational time of equipment (i.e., pumps, dewatering filters, presses) or quantity of material trucked to a landfill. However, these estimates can be impacted by sludge mixture (i.e., primary versus secondary) and percent solids. These factors can vary and thus significantly impact estimates of emissions. On the other hand, air emissions are even more difficult to estimate. It is impractical to "capture" the air emissions and measure the quantity of air emitted from an aeration basin. The greatest factor affecting the quantity of air emission is most probably atmospheric conditions which are impossible to estimate. In theory these emission rates should be controlled or controllable, but in practice they are not and procedures have not been developed for accurate measurement of the emission rates.

At the St. Regis Paper Co. facility surface aerators were employed and the interpretation of the air emission data is difficult since the actual volume of air involved in the aeration process could not be measured. As a result, the air emission pollutant masses for this facility were not included as a discrete entry in the mass balance calculations.

For Bergstrom Paper Co. and Wisconsin Tissue Mills, the blower capacity has been utilized as records are not maintained on actual air flow to the process. Therefore estimates of air emissions based on blower capacities, should be considered rough estimates only.

The dewatered sludges are very complex. The EPA has developed preliminary analytical methods for the priority pollutants. The analytical methods can be significantly impacted by the complexities of the sample matrices. The samples analyzed were very complex. As a result the detection limits were greater due to matrices interference. The program included analysis for several non-conventional pollutants. The analytical methods developed by the EPA had not been used to analyze for the non-conventional pollutants. One of the goals of this program was to assess the applicability of the current protocols with modification for analysis of the non-conventional pollutants. Methods development was beyond the scope of this project. In summary, the current methodologies require further development to minimize the matrix interferences which affect the analytical sensitivity.

REFERENCES

1. Walden, C.C. Review Paper - "The toxicity of Pulp and Paper Mill Effluents and Corresponding Measurement Procedures." Water Research, Vol. 10, 1976.

2. Swan, E.P. "Resin and Fatty Acids of Canadian Pulpwoods." A Review of Literature, Canadian Department of Forestry, 1973.

3. Sinclair, G.D., and Dymond, D.K. "Variation in acetone-soluble extractives from jackpine with age and tree diameter." Canadian Journal of Forest Res., 1973.

4. Martins, D., Gordon, R.W. and Servizi, J.A. "Toxicity and Treatment of Deinking Wastes Containing Detergents." International Pacific Salmon Fisheries Commission, Progress Report No. 25, 1971.

5. Zambrano, J.J. and Walter, K.J. New York State Department of Conservation, "A Survey of PCB in Wastewater from Paper Recycling Operations," presented at the Northeast Regional Meeting of the Paper Industry for Air and Stream Improvement, Inc., November 1978.

6. Bulkey Dunton & Co., New York, New York, "Lockwood's Directory of the Paper and Allied Trades, 1979."

7. Screening and Verification Program and Toxic and Nonconventional Pollutants in Pulp, Paper and Paperboard Wastewaters, Gulf South Research Institute, April, 1980.

8. Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants. U.S. Environmental Protection Agency, Cincinnati, Ohio, March 1977, revised April 1977.

9. National Council for Air and Stream Improvement of the Paper Industry and Special Internal Report.

10. Interim Methods for the Measurement of Organic Priority Pollutants in Sludges, U.S. EPA, EMSL, Cincinnati, Ohio. September 1979.

11. Warner, J.S., et al., Analytical Procedures for Determining Organic Priority Pollutants in Municipal Sludges. U.S. Environmental Protection Agency, EPA 600/2-80-030, MERL, Cincinnati, Ohio, March 1980.

12. EPA, EMSL Method B100 for Semivolatile Organic Components.

13. U.S. EPA, EMSL Method MX00 - Method for the Analytical Determination of Chlorinated Pesticides and Polychlorinated Biphenyl in Municipal Sludge by Gas Chromatography with Electron Capture Detection.

APPENDIX A

BERGSTROM PAPER COMPANY
NEENAH, WISCONSIN
DESIGN CRITERIA

Biological System	First Stage	Second Stage
FEED		
Source	primary clarifier	effluent first stage
Flow - gpm (gpd)	3,829 (5,513,760)	3,844 (5,535,360)
BOD_5 - lb/d (mg/l)	24,200 (526)	5,000 (108)
S.S. - lb/d (mg/l)	20,320 (442)	6,500 (141)
pH	8 - 9	7 - 8
EFFLUENT		
To	second stage aeration	outfall & reuse
BOD_5 - lb/d (mg/l)	5,000 (108)	1,200 (28)
S.S. - lb/d (mg/l)	6,500 (141)	2,500 (58)
AERATION TANK		
LxWx water depth - ft	50x90x18	50x90x16'9"
Operating volume - gal	605,880	563,800
Retention time - hrs	2.64	2.44
MLSS - mg/l	10,400	2,000
MLVSS/MLSS	0.7	0.7
D.O. - mg/l	0.5 - 1.0	2 - 3
F/M - lb BOD_5/d/lb MLSS	0.3	0.3
BOD loading - lb BOD_5/d/1000 ft^3	299	66
Design O_2 transfer - lb/hr	1,040	550
Sludge age - days	8.3	9.5
Sludge yield - lb sludge/lb BOD_5 removed	0.5	0.5
SVI	100 - 150	75 - 125

(BERGSTROM PAPER design criteria, cont'd)

Biological System	First Stage	Second Stage
SETTLING TANK		
LxWx water depth ~ ft	50x160x13'3"	50x160x11'10"
Surface area - ft^2	8,000	8,000
Operating volume - gal	792,880	707,907
Retention time - hrs	3.45	3.07
Sludge blanket depth - ft	3	3
Sludge recycle - % of feed flow	200	150
Surface loading - $gal/d/ft^2$	689	692
SLUDGE WASTING		
Wasting from	aeration liquid header	second stage aeration tank
Wasting to	air flotation thickener	first stage aeration tank
Flow - gpm	227	242
Concentration - mg/l	10,400	2,000
SCUM		
Flow to	sludge recycle channel	sludge recycle channel
AERATION SYSTEM		
Aeration system type & supplier	Jet aerator by Penberthy Houdaille	
Blowers installed	3 @ 200 hp each	
Blowers operating	2 @ 170 bhp each	
Blower capacity - cfm	3075	
Blower discharge - psig	8.5	
Pumps installed	3 @ 50 hp each	3 @ 50 hp each
Pumps operating	2 @ 41 bhp each	2 @ 41 bhp each
Pump capacity - gpm	6,750	6,750
Pump TDH - ft	23	23
Aerators	3 rows of 2	3 rows of 2

Primary clarifier - 120' dia. x 14' SWD
a) Design - 8 mgd
   Surface overflow rate @ 8 mgd = 760 $gal/day/ft^2$
   Weir overflow rate @ 8 mgd = 11,000 gal/day/ft
   Retention time @ 8 mgd = 3.5 hours

Sludge Dewatering

SDM 80" "P" Tait Andritz Filter Presses
45 T/D Primary OD
15 T/D Secondary OD
Sludge Cake - 39% solids
2 Presses - 75% of time

APPENDIX B

ST. REGIS PAPER COMPANY
SARTELLE, MINNESOTA
DESIGN CRITERIA

Design loadings and conditions	
Design flow, mgd	6.9
Influent wastewater characteristics	
Design BOD5, lb/day	8,280
Design suspended solids, lb/day	5,700
Expected Effluent Quality	
BOD5 concentrations, mg/l	40
Settleable solids concentration, ml/l	5
Temperature	
Ambient temperature, °F	
Winter (January)	
Daily average	10
Average minimum	0
Summer (July - August)	
Average daily	71
Average maximum	83
Mill effluent temperatures, °F (estimated)	
Summer	90-100
Winter	50

(St. Regis design criteria, cont'd)

Aeration basins	
Number	Two
Design criteria	3.47 hrs retention of 6.9 mgd w/25% recycle
Capacity	625,000 gal/basin
Dimensions	110'x60'x13' SWD plus 2' freeboard
Construction	Reinforced concrete basins
Mechanical aerators	
Oxygen transfer coefficient (a)	0.87
Oxygen saturation coefficient (b)	0.94
Number	Four total; two per basin
Minimum DO to be maintained in the basin	0.5 mg/l
Oxygen requirement/basin,	
maximum	176 lbs O_2/hr
average	132 lbs O_2/hr
Aerator motor capacity/basin, hp	
Average conditions	60-65
Design conditions	80-90
Arrangement	As shown on plot plan
	Tranfer 3.5 lb O_2/hr/shaft hp at standard conditions
Capacity provided	100 hp/basin
Type and control	2-50 hp surface entrainment aerators basin, platform-mounted, two-speed, turbine type, with *automatic control of oxygen transfer
Final Clarifiers	
Number	Two
Overflow Rate	600 gpd/sf
Main dimensions	85' dia., 8' SWD
Volume (each)	345,000 gal
Detention time	2.4 hrs, 6.9 mgd
Type	Center feed clarifiers w/hydraulic type sludge withdrawal mechanism and provision to add surface skimmers
Construction	Reinforced concrete

(St. Regis design criteria, cont'd)

Activated sludge recycle pumps	
Number	Two plus one common spare
Capacity	50% of design flow of 6.9 mgd w/two pumps operating
Type	Centrifugal, non-clog sludge pump
Capacity (each)	1,250 gpm
Control	Manual throttling w/flow rate indicator
Sludge wastage control	Magnetic flowmeter w/indicator recorder
Flow splitting box	
Function	To control and split flow into aeration basins and final clarifiers
Number	Three (one before and one following aeration basins and one following clarifiers)
Main dimensions	5'x6'x7' SWD w/2' freeboard
Construction	Reinforced concrete
Sludge reaeration tank	
Number	One
Retention at average flow rate	2.7 hr
Capacity	18,600 gal.
Main dimensions	20' dia. x 8' SWD
Construction	Reinforced concrete
Aerator for sludge reaeration	
Number	One
Endogenous oxygen required	15 lb O_2/hr/1,000 lb MLVSS under aeration
Total oxygen required	35 lb O_2/hr
Minimum DO to be maintained	3.0 mg/l
Aerator motor capacity	25 hp
Type	Turbine-type platform mounted, surface entrainment

(St. Regis design criteria, cont'd)

Gravity biological sludge thickener	
Number	One
Design loading	6 lb/ft^2/day
Influent solids	5,000 lb/day
Dimensions	35' dia. 14' deep
Capacity	100,000 gal
Construction	Reinforced concrete
Type	Circular, centerfeed, rim overflow unit with heavy duty picket-type thickening mechanism and plow-type rotary sludge scraper mechanism.
Thickened sludge pumps	
Number	One plus one spare unit
Sludge solids to be pumped	2% by weight
Capacity	25 gpm each
Type	Positive displacement
Control	Manual throttling
Nutrient addition (design conditions)	
Phosphorous required	One lb P/100 lb BOD_5 removed
Nitrogen required	5 lb N/100 lb BOD_5 removed
BOD removed	8,280 lb/day
Phosphorous required	85 lb P/day
Nitrogen required	415 lb N/day
Phosphoric acid required, (60% concentration)	51 gal/day
Anhydrous ammonia required	500 lb/day
Nutrient storage facilities	
Ammonia	
Type	Anhydrous
Number	One

APPENDIX C

SUMMARY OF ANALYTICAL METHODS

GC VOLATILE ORGANIC ANALYSIS - EPA No. 501.2

1. Scope and Application

1.1 This method is suitable for the determination of halogenated volatile organic priority pollutants. The following compounds have been determined by this method:

1,2-dichloroethane	1,1-dichloroethylene
1,2-dichloropropane	bromodichloromethane
methylene chloride	carbon tetrachloride
1,1,2,2-tetrachloroethane	chlorobenzene
1,1,2,2-tetrachloroethylene	2-chloroethylvinyl ether
chloroform	trans-1,2-dichloroethylene
cis-1,3-dichloropropane	trans-1,3-dichloropropene
dibromochloromethane	1,1,1-trichloroethane
1,1-dichloroethane	1,1,2-trichloroethane
trichloroethylene	trichlorofluoromethane

1.2 This method is applicable to the compounds in pulp/paper industrial effluents.

2. Summary of Method

2.1 Withdraw 5 ml sample from the 155 ml serum vial and replace with 5 ml of chloroform free hexane. Shake vigorously for one-half hour and analyze organic layer by GC/ECD.

3. Interferences

3.1 Method blanks were run by extracting with organic-free water and analyzing it in a normal manner. Sample blanks were prepared from organic-free water and carried through the sampling and handling protocol.

4. Reagents

4.1 Organic-Free Water:

4.1.1 A Millipore Super-Q water system was used to generate organic-free water.

4.2 Stock standard solutions are prepared in organic-free water.

4.3 All other reagents were of chromatographic quality.

5. Calibration

5.1 Standards were injected at various concentration levels to check linearity of instrument.

6. Quality Control

6.1 Field blanks were collected to validate the sampling, storage and analysis process. Laboratory blanks were analyzed to validate the integrity of the analysis.

6.2 Linearity of the entire system was checked over the range of concentrations commonly encountered in sample analyses. Composite standards in various dilutions were used for GC/ECD linearity checks.

7. Sample Collection, Preservation and Handling

7.1 Samples were collected in glass containers having a total volume in excess of 40 ml. Sample bottles were filled in such a manner that no air bubbles passed through the sample as the bottle was being filled. Bottles were sealed so that no air bubbles were trapped in them. The hermetic seal was maintained until time of analysis.

7.2 The samples were iced at the time of collection and maintained at ice temperature until extraction.

8. GC Analysis

8.1 The GC conditions are given in Table 17. Inject 5 microliters of extract with the oven temperature at 40°C. Hold at 40°C for 3 minutes then program the oven temperature rise to 120°C at 8°C/minute.

8.2 Collect continuous GC data throughout the run until the last compound of interest has eluted.

TABLE 17

GC VOLATILE ORGANIC ANALYSIS PARAMETERS

Gas chromatographic conditions
Column: 3% OV-1 on 100/120 gas chrom Q
Flow rate: 30 ml/min
Detector temperature: 350°C
Injector temperature: 250°C
Temperature program 40°C for 3 min to 120°C @ 8°C/min
Detector: electron capture (ECD)

9. Identification - Quantification

9.1 Identify the determinate compounds in a sample by comparing the GC data of the sample with the GC data of standards. The presence of a compound was confirmed by the occurrence of a peak at the predicted retention time ± 1 min.

9.2 When the GC data for a sample meets the above criteria for detection, the concentration (C_x) is calculated as follows:

$$C_x = \frac{(A_x)\ (C_s)\ (\text{volume correction factor})}{A_s}$$

where A_x and A_s are the integrated peak areas from the characteristic peaks of the pollutant in the sample and the pollutant in the standard, and C_s is the concentration of the pollutant in the standard.

9.3 Report results in ug/l sample water, ug/6 liters of air emissions or ug/kg of dewatered sludge (as a wet weight).

GC SV/AN ANALYSIS[9]

1. Scope and Application

1.1 This procedure is suitable for GC/FID determination of selected SV/AN priority pollutants which are amenable to organic extraction and GC resolution.

1.2 The following compounds have been determined by this method:

abietic acid	isopimaric acid
linoleic acid	linolenic acid
monochlorodehydroabietic acid	naphthalene
2-chlorophenol	oleic acid
dehydroabietic acid	dichlorodehydroabietic acid
2,4-dichlorophenol	pimaric acid
tetrachloroguaiacol	trichloroguaiacol
2,4,6-trichlorophenol	

1.3 This method is applicable to the determination of these compounds in pulp/paper industrial effluents.

1.4 The sensitivity of the method is not usually dependent upon the level of interferences but rather instrumental limitations. The limits of detection of 5 ug/l represent sensitivities that can be achieved in wastewaters under optimum operating conditions.

2. Summary of Method

2.1 A one-liter sample of wastewater is acidified to pH 2 and serially extracted with methylene chloride using separatory funnel techniques. The resulting acid-neutral extract is dried and concentrated to a volume of 1 ml or less and derivatized with diazomethane. GC conditions are described which allow for the measurement of the compounds in the extract.

3. Interferences

3.1 All materials and glassware were demonstrated to be free from interferences under the conditions of the analysis by running method blanks.

4. Reagents

4.1 Preservatives:

4.1.1 Sodium hydroxide - (ACS) 10 N in distilled water.

4.1.2 Hydrochloric acid - (ACS) Mix equal volumes of concentrate HCl with distilled water (1+1) and 1 N.

4.2 Methylene chloride - Pesticide quality or equivalent.

4.3 Sodium sulfate - (ACS) granular, anhydrous (purified by heating at 400°C for 4 hrs).

4.4 Diazomethane - Derivatizing reagant (prepared from N-methyl,N'-nitro-N-nitrosoguanidine [Aldrich]).

5. Quality Control

5.1 Standard QA practices were used with this method. Field blanks were collected to validate the sampling, storage and analysis process. Laboratory blanks were analyzed to validate the integrity of the analysis.

5.2 The linearity of the system was checked over the range of concentrations commonly encountered in sample analyses. A composite standard in various dilutions was used for GC linearity checks.

6. Sample Collection, Preservation and Handling

6.1 Grab samples were collected in glass containers. Conventional sampling practices were followed. Composite samples were collected in refrigerated glass containers.

6.2 The samples were iced or refrigerated from the time of collection until extraction. At the sampling location the glass container was filled with sample, and the sample pH adjusted from 10 to 10.2 with sodium hydroxide.

7. Sample Extraction

7.1 Measure 1 liter of sample using a graduated cylinder into a 2 liter separatory funnel; add the internal standard solution. Adjust the sample pH to 2 with hydrochloric acid.

7.2 Add 60 ml methylene chloride to the graduated cylinder and rinse. Transfer the rinse solvent and 65 ml more CH_2Cl_2 into the separatory funnel and extract the sample by shaking the funnel for 2 minutes with periodic venting to release vapor pressure. Allow the organic layer to separate from the water phase for a minimum of 10 minutes. Recover methylene chloride layer, and repeat the sample extraction with two additional 50 ml portions of methylene chloride in like fashion.

7.3 Combine all fractions of methylene chloride (rinses and extracts). Filter extract through a drying column containing 3-4 inches of anhydrous sodium sulfate, and collect it in a 500 ml Kuderna-Danish (K-D) flask equipped with a 10 ml concentrator tube. Rinse the Erlenmeyer flask and column with 20-30 ml methylene chloride to complete the quantitative transfer.

7.4 Add 1-2 clean boiling chips to the flask and attach a three-ball Synder column. Prewet the Synder column by adding about 1 ml methylene chloride to the top. Place the K-D apparatus in an oil bath so that the concentrator tube is partially immersed in hot oil and the entire lower rounded surface of the flask is bathed in heat. Adjust the vertical position of the apparatus and the oil temperature as required to complete the concentration in 15-20 minutes. When the apparent volume of

liquid reaches 1 ml, remove the K-D apparatus and allow it to drain for at least 10 minutes while cooling. Complete concentration with dry nitrogen stream.

8. GC Analysis

8.1 The GC conditions are given in Table 18. Inject 5μ liters of derivatized extract with the oven temperature at 140°C. Hold at 140°C for 3 minutes then program the GC temperature to rise to 235°C at 2°/min.

8.2 After the solvent front and excess Diazomethane are eluted collect continuous GC data throughout the chromatogram until the last compound of interest has eluted.

9. Identification and Quantification

9.1 Identify the compounds of interst in a sample by comparing the GC data of the sample with the GC data of the composite standard analyzed that day. The presence of a compound is confirmed in a sample by the occurrence of a peak at the predicted retention time ± 1 min.

9.2 Report results in ppb uncorrected for recovery.

GC SLUDGE ANALYSIS[10,11,12]

1. Scope and Application

No acceptable methods presently exist for the measurement of trace levels of acidic priority pollutants and the additional compounds in sludges. In this study, however, where substantial concentrations of sludges would be required to substantially contribute to a materials balance assessment, EPA procedures were found adaptable. The following will detail the portions of the referenced procedures used.

1.1 Weigh accurately 5 g sludge and transfer quantitatively to tissuemizer tube. Add 20 ml organic-free water.

1.2 Spike with heptadecanoic acid.

1.3 Acidify to pH <2 with concentrated HCL.

1.4 Add 25 ml nanograde dichloromethane and homogenize for 1 minute.

1.5 Transfer to 50 ml centrifuge tube and centrifuge in bench top unit at maximum speed for 15 min.

1.6 Recover dichloromethane and repeat steps 1.4 thru 1.6.

TABLE 18

SEMI-VOLATILE ORGANICS
SUMMARY OF ANALYSIS PROCEDURES

1. SV/AN analysis by GC[9]

Extraction conditions

1 liter sample (pH >10)
Adjust pH <2 with concentrated HCl
Spike with heptadecanoic acid (recovery standard)
Serial extraction with dichloromethane (125, 50, 50 ml)
Break emulsions by glass wool filtration
Dry with sodium sulfate
Concentrate sample by Kuderna-Danish evaporation to 1.0 ml

Derivitization conditions (diazomethane derivatives)

Place 1.0 ml derivatizing reagent (diazomethane in diethyl ether/methanol 9:1) in a reactavial. Inject 50 µl of sample and let stand 1 hr at room temperature.

GC - Perkin-Elmer Sigma 1

Column: 5% SP 2330 on 100/120 chromosorb W/AW
Flow rate: 30 ml/min
Detector temp: 350°C
Injector temp: 250°C
Temperature program: 140°C for 3 min to 235°C for 5 min at 8°C/min.
Detector: Flame ionization (FID)

2. SV/AN analysis by GC/MS[7]

Extraction conditions

1 liter sample (pH 10)
Adjust pH <2 with concentrated HCl
Spike with deuterated internal standards
Serial extraction with dichloromethane (125, 50, 50 ml)
Break emulsions by glass wool filtration or solvent addition
Dry with sodium sulfate
Concentrate sample by Kuderna-Danish evaporation to 1.0 ml
Add 100 µg/vial d10 anthracene
Store sample in 5.0 ml serum vial with teflon/rubber septum

MS - HP 5985

Amu range: 35-450
Scan speed: 300 amu/sec
A/D per 0.1 amu: 3

Table 18 (cont'd)

GC - HP 5840

Column: SE-30 SCOT (SGE D grade >40,000 Neff)
Flow rate: 22 cm/sec at 200°C
Injection volume: 1 ml, splitless injection
Temperature program: 30°C to 260 at 6°/min

Derivatization conditions (trimethylsilyl derivatives)

Place 100 µl samples plus 50 ml MSTFA in conical vial, heat for 15 min. at 70°C, cool to room temperature prior to injection.

1.7 Combine dichloromethane fractions and dry over anhydrous sodium sulfate.

1.8 Reduce volume to 1.0 ml by Kuderna-Danish fractionation/dry nitrogen stream.

2. PCB Analysis

Reduce extract to dryness under dry nitrogen. Reconstitute with 6% ethyl ether in hexane. Apply to florisil column and elute with 6% ethyl ether in hexane. Concentrate eluate and analyze by GC/ECD.

3. SV/AN Analysis

Derivatize extract without fluorisil treatment with equal volume of Diazomethane derivatizing reagent. Analyze derivatized extract by the NCASI procedure[9] using GC/FID/ECD with SP-2330 substrate. ECD was used for chlorophenols to reduce tendencies for positive interferences by FID.

APPENDIX D

ANALYTICAL RESULTS

TABLE 19 BERGSTROM PAPER COMPANY
SUMMARY OF RAW WASTEWATER ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19	09/20
Volatiles										
chloroform	23	2960	2295	3537	1600	2150	2002	3347	1354	
dichlorobromomethane#	48									
trichloroethylene#	87	2292	156	1260	120	1292	1448	1562	635	
Semivolatiles										
2,4,6-trichlorophenol	21	58	21		57	ND	83		ND	
2,4-dichlorophenol	31	28	ND		10	ND	12		ND	
naphthalene	55	313	291		364	ND	393		252	
dehydroabietic acid	131	5371	4026		4871	4789	7110		6905	
isopimaric acid	132	344	13		312	205	524		445	
pimaric acid	133	149	ND		ND	ND	ND		ND	
oleic acid	134	406	220		678	611	1200		532	
linoleic acid	135	294	63		477	355	774		322	
monochlorodehydroabietic acid	139	352	93		264	936	180		ND	
Other										
cyanide	121	ND	10	10	25	40	25	ND	100	
PCB-1254	107	51	ND		ND	ND	ND			ND
PCB-1016	112	ND	25		7.4	ND	110			12.5

Notes:
1. Results expressed in micrograms/liter.
2. ND = not detected.
3. # = compounds coelute.

TABLE 20. BERGSTROM PAPER COMPANY
SUMMARY OF AIR EMISSION ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19
Volatiles (cryogenic)									
1,1,1-trichloroethane	11	ND	ND	0.3	ND		ND	ND	
chloroform	23	2.8	1.2	1.1	5.0		0.7	3.4	
dichlorobromomethane#	48								
trichloroethylene#	87	0.3	ND	0.25	0.2		3.1	0.2	
Semivolatiles									
2,4,6-trichlorophenol	21	ND	ND(ND)	8/ND	ND		ND(ND)	ND	ND
dehydroabietic acid	131	7	25(20)	25/10	16		49(110)	134	6
isopimaric acid	132	ND	ND(ND)	ND/9	ND		ND(13)	ND	ND
pimaric acid	133	9	ND(ND)	ND/ND	ND		ND(ND)	14	ND
oleic acid	134	ND	ND(ND)	26/ND	ND		11(17)	ND	6
linoleic acid	135	ND	ND(ND)	ND/ND	ND		ND(5)	110	ND
monochlorodehydroabietic acid	139	ND	ND(ND)	48/25	ND		6(20)	ND	ND
3,4,5-trichloroguaiacol	141	40	35(58)	114/109	33		59(ND)	17	46
Recovery of heptadecanoic acid									
percent recovery		44	72(53)	34			69(39)	83	88

Notes:

1. Results expressed in micrograms/liter of air emissions.
2. ND = not detected.
3. # = compounds coelute.
4. ( ) = blanks.
5. / = duplicates.

TABLE 21. BERGSTROM PAPER COMPANY
SUMMARY OF DEWATERED SLUDGE ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19
Semivolatiles									
abietic acid	130		ND	24600	ND		ND	ND	ND/ND
dehydroabietic acid	131		8540	2180	ND		8030	ND	ND/ND
isopimaric acid	132		ND	11200	ND		13050	10700	ND/ND
pimaric acid	133		8200	ND	ND		2010	ND	ND/ND
oleic acid	134		680	ND	8730		ND	ND	ND/ND
monochlorodehydroabietic acid	139		1670	ND	5860		1005	ND	ND/ND
Other									
PCB-1254	107		ND	410	2090/4540*		ND	3370	5820
PCB-1016	112		2120/1720	ND	ND		2050/730*	ND	ND

Notes:

1. Results expressed in micrograms/liter of dewatered sludge.
2. ND = not detected.
3. # = compounds coelute.
4. / = duplicates.
5. * = undigested/digested samples.

TABLE 22. BERGSTROM PAPER COMPANY
SUMMARY OF FINAL EFFLUENT ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19	09/20
Volatiles										
chloroform	23	84/26	ND	33	ND	85	78	ND	54	28
1,1,1-trichloroethane	11	2/ND	ND	ND	ND	2	2	ND	ND	ND
dichlorobromomethane#	48									
trichloroethylene#	87	15	15	12	7	15	9	8	9	12
Semivolatiles										
2,4,6-trichlorophenol	21	55	ND	38	74	46	63	ND	185	
2,4-dichlorophenol	31	13	ND	6	10	9	12	ND	41	
naphthalene	55	ND	ND	ND	ND	ND	64	ND	ND	
abietic acid	130	ND	16	ND	ND	ND	ND	ND	ND	
dehydroabietic acid	131	ND	34	26	26	ND	ND	81	286	
isopimaric acid	132	ND	ND	ND	ND	ND	35	ND	ND	
oleic acid	134	23	ND	ND	ND	11	76	13	ND	
monochlorodehydroabietic acid	139	ND	ND	ND	ND	513	104	ND	ND	
3,4,5-trichloroguaiacol	141	ND	ND	ND	ND	75	91	65	ND	
tetrachloroguaiacol	142	55	ND	ND	ND	ND	ND	ND	106	
Recovery of heptadecanoic acid										
percent recovery		100	117	121	120	94	99	72	103	

Notes:

1. Results expressed in micrograms/liter.
2. ND = not detected.
3. # = compounds coelute.
4. / = duplicates.

TABLE 23. WISCONSIN TISSUE MILLS
SUMMARY OF RAW WASTEWATER ANALYTICAL RESULTS

Pollutant		Sample date								
Name	EPA No.	09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19	09/20
Volatiles										
chloroform	23	164			150		455		67	319
Other										
cyanide	121	ND	10	ND	90	150	100	25	20	
PCB-1016	112	18	62	123	ND	2.2	ND		5	18

Notes:

1. Results expressed in micrograms/liter.
2. ND = not detected.

TABLE 24. WISCONSIN TISSUE MILLS
SUMMARY OF AIR EMISSION ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19
Volatiles (cryogenic)									
chloroform	23	0.7	1.9(ND)	1.6	3.5			2.2(ND)	0.9
Semivolatiles (alkali)									
dehydroabietic acid	131		46/49 (21/11)	ND(23)	18/91		27/34		12
isopimaric acid	132		ND	ND	ND		6		ND
pimaric acid	133		ND	5(ND)	13		ND(ND)		ND
oleic acid	134		7/11 (ND/10)	ND(7)	6		9(ND)		ND
linoleic acid	135		ND(ND)	ND(ND)	ND		ND(7)		ND
monochlorodehydroabietic acid	139		5/6 (12/8)	ND(13)	24/8		ND/ND		ND
3,4,5-trichloroguaiacol	141		ND(40)	ND(58)	37		75/24 (48)		9
Recovery of heptadecanoic acid									
percent recovery			75(75)	14(66)			59(57)		

Notes:
1. Results expressed in micrograms/liter of air emissions.
2. ND = not detected.
3. ( ) = blanks.
4. / = duplicates.

TABLE 25. WISCONSIN TISSUE MILLS
SUMMARY OF DEWATERED SLUDGE ANALYTICAL RESULTS

Pollutant		Sample date							
Name	EPA No.	09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19
Semivolatiles									
bis(2-ethylhexyl)phthalate	66		ND	33100			1670	46600	ND
abietic acid	130		8200	ND			ND	ND	ND
isopimaric acid	132		ND	14900			ND	ND	ND
oleic acid	134		3480	ND			ND	ND	ND
linoleic acid	135		700	ND			ND	ND	ND
monochlorodehydroabietic acid	139		840	ND			21000	ND	18800
Other									
PCB-1260	111		3240	ND			ND	ND	ND
PCB-1016	112		ND	790/740*			123	902/700*	790

Notes:

1. Results expressed in micrograms/liter of dewatered sludge.
2. ND = not detected.
3. Detection limit 100 micrograms/kilogram.
4. * = undigested/digested samples.

TABLE 26. WISCONSIN TISSUE MILLS
SUMMARY OF FINAL EFFLUENT ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 09/12	09/13	09/14	09/15	09/16	09/17	09/18	09/19	09/20
Volatiles										
chloroform	23	18/17	29		41	12	33	14	24	
Semivolatiles										
abietic acid	130	ND	ND	ND	ND	ND	ND	ND	142	
dehydroabietic acid	131	ND	ND	225	ND	232	ND	ND	ND	
isopimaric acid	132	ND	ND	ND	8	ND	ND	ND	25	
oleic acid	134	48	145	34	ND	ND	ND	ND	15	
linoleic acid	135	ND	ND	ND	ND	ND	ND	ND	5	
monochlorodehydroabietic acid	139	ND	196	ND	831	ND	ND	115	467	
Recovery of heptadecanoic acid										
percent recovery		125	107	146	65	93	98	117	82	131

Notes:
1. Results expressed in micrograms/liter.
2. ND = not detected.

TABLE 27. ST. REGIS PAPER COMPANY
SUMMARY OF RAW WASTEWATER ANALYTICAL RESULTS

Pollutant		Sample Date					
Name	EPA No.	10/08	10/09	10/10	10/11	10/12	10/13
Volatiles							
Chloroform	23	9		9		12	
Semivolatiles							
abietic acid	130		117	1440			
dehydroabietic acid	131		201	1000			
isopimaric acid	132		102	1150			
pimaric acid	133		92	150			
oleic acid	134		74	114			
linoleic acid	135		78	69			

Notes:
1. Results expressed in micrograms/liter.

TABLE 28. ST. REGIS PAPER COMPANY
SUMMARY OF AIR EMISSION ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 10/08	10/09	10/10	10/11	10/12
Volatiles (cryogenic)						
Chloroform	23	0.34	0.15	0.19	ND	
Semivolatiles (alkali)						
dehydroabietic acid	131	40	ND		10	
isopimaric acid	132	8	ND		7	
pimaric acid	133	6	ND		6	
Recovery of heptadecanoic acid percent recovery		70	57		61	

Notes:

1. Results expressed in micrograms/liter of air emissions.
2. ND = not detected.

TABLE 29. ST. REGIS PAPER COMPANY
SUMMARY OF DEWATERED SLUDGE ANALYTICAL RESULTS

Pollutant		Sample date			
Name	EPA No.	10/08	10/09	10/10	10/11
Semivolatiles					
abietic acid	130	3510	ND	ND	33500
dehydroabietic acid	131	54400	ND	ND	44500
isopimaric acid	132	1170	ND	34700	ND
oleic acid	134	ND	3730	ND	ND

Notes:

1. Results expressed in micrograms/liter.
2. ND = not detected.

TABLE 30. ST. REGIS PAPER COMPANY
SUMMARY OF FINAL EFFLUENT ANALYTICAL RESULTS

Pollutant Name	EPA No.	Sample date 10/09	10/10	10/11	10/12	10/13
Volatiles						
Chloroform	23	ND	6	6	5	
Semivolatiles						
abietic acid	130	24	ND	ND	13	22
dehydroabietic acid	131	12	ND	ND	13	5
pimaric acid	133	56	ND	ND	21	65
oleic acid	134	ND	117	54	ND	138
linoleic acid	135	87	ND	ND	22	82
Recovery of heptadecanoic acid						
percent recovery		78	41	58	88	120

Notes:

1. Results expressed in micrograms/liter.
2. ND = not detected.

TABLE 31

SUMMARY OF ANALYTICAL RESULTS BY
GULF SOUTH RESEARCH INSTITUTE

		Sample Number											
EPA NO.	Compound	Berg 91479	Berg 92079										
44	methylene chloride	8	3										
49	trichlorofluoromethane												
13	1,1-dichloroethane												
23	chloroform	9000	6200										
10	1,2-dichloroethane												
11	1,1,1-trichloroethane	81	60										
15	1,1,2,2-tetrachloroethane												
6	carbon tetrachloride												
48	dichlorobromomethane	16	21										
87	trichloroethylene	710	750										
51	dibromochloromethane												
4	benzene												
47	bromoform												
85	tetrachloroethylene												
86	toluene	5	5										
7	chlorobenzene												
38	ethylbenzene	2	3										
143	xylenes	10	12										

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

VOLATILE ORGANICS MILL NO. B

EPA NO.	Compound	Sample Number											
		B-Blk	B-91279 C	B-91379 C	B-91479 C	B-91579 C	B-91679 C	B-91779 C	B-91879 C	B-91979 C			
70	diethyl phthalate												
68	di-n-butyl phthalate						100			5			
67	butyl benzyl phthalate												
66	bis(2-ethylhexyl) phthalate	190	88	17	75	36	180	63	57	55			
69	di-n-octyl phthalate												
65	phenol		4*	2*	3*	5*	8*	5*	2*	3*			
24	2-chlorophenol												
31	2,4-dichorophenol		6	**	33	13	12	60	56	27			
21	2,4,6-trichlorophenol		62	**	83	29	50	150	120	110			
64	pentachlorophenol												
22	p-chloro-m-cresol												
59	2,4-dinitrophenol												
134	oleic acid		400	290	1500	980	1800	1300	1000	460			
135	linoleic acid		150	37	460	410	330	490	300	200			
136	linolenic acid												
133	pimaric acid		35	**	100	87	130	100	90	64			
132	isopimaric acid		110	20*	230	180	120	180	130	110			
131	dehydroabietic acid		1000	770	2300	1600	1000	1600	1600	1500			
130	abietic acid		**	**	**	450	89	130	31	81			

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

SEMIVOLATILE ORGANICS MILL NO. B

		Sample Number											
EPA NO.	Compound	B-Blk	B-91279 C	B-91379 C	B-91479 C	B-91579 C	B-91679 C	B-91779 C	B-91879 C	B-91979 C			
141	trichloroguaiacol		**	**	5*	5*	2*	20	12	3*			
142	tetrachloroguaiacol		**	**	13	8	4*	14	15	9			
139	1-Cl-dehydroabietic acid		50*	140	200	110	110	180	120	72			
140	Cl_2-dehydroabietic acid												
137	epoxystearic acid												
138	dichlorostearic acid												
54	isophorone												
55	naphthalene		150	180	310	240	180	280	250	140			
1	acenaphthene				4	2			1				
77	acenaphthylene												
78	anthracene							8					
39	fluoranthene												
84	pyrene												
76	chrysene												
% Recovery	stearic acid D35												
	phenol D5												
	naphthalene D8												
	diamyl phthalate												

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

SEMIVOLATILE ORGANICS MILL NO. B

EPA NO.	Compound	Sample Number											
		Wis Tis 91279	Wis Tis 91479										
44	methylene chloride	9											
49	trichlorofluoromethane												
13	1,1-dichloroethane												
23	chloroform	330	1100										
10	1,2-dichloroethane												
11	1,1,1-trichloroethane												
15	1,1,2,2-tetrachloroethane												
6	carbon tetrachloride												
48	dichlorobromomethane												
87	trichloroethylene												
51	dibromochloromethane												
4	benzene												
47	bromoform												
85	tetrachloroethylene												
86	toluene	1	3										
7	chlorobenzene												
38	ethylbenzene	13											
143	xylenes	74	2										

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

VOLATILE ORGANICS MILL NO. W

EPA NO.	Compound	Sample Number											
		W-Blk	W-91279 PI	W-91379 PI	W-91479 PI	W-91579 PI	W-91679 PI	W-91779 PI	W-91879 PI	W-91979 PI			
70	diethyl phthalate					56				29			
68	di-n-butyl phthalate		21	1100	280	19		42	63	760			
67	butyl benzyl phthalate												
66	bis(2-ethylhexyl) phthalate		55	96	100	13	8	280	25	20			
69	di-n-octyl phthalate												
65	phenol		30	10*	14*	9*	9*	2*	22	13			
24	2-chlorophenol												
31	2,4-dichorophenol												
21	2,4,6-trichlorophenol												
64	pentachlorophenol												
22	p-chloro-m-cresol												
59	2,4-dinitrophenol												
134	oleic acid		1800	490*	130*	340*	84*	630*	810	260*			
135	linoleic acid		380	270	**	102	**	61	150	53			
136	linolenic acid												
133	pimaric acid		400	230	250	280	200	81	200	240			
132	isopimaric acid		420	580	200	370	560	300	190	160			
131	dehydroabietic acid		2100	2300	1300	1500	1900	1200	1400	1600			
130	abietic acid		2400	1900	1300	1600	1500	750	1200	1300			

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

SEMIVOLATILE ORGANICS MILL NO. W

		Sample Number											
EPA NO.	Compound	W-Blk	W-91279 PI	W-91379 PI	W-91479 PI	W-91579 PI	W-91679 PI	W-91779 PI	W-91879 PI	W-91979 PI			
141	trichloroguaiacol												
142	tetrachloroguaiacol												
139	1-Cl-dehydroabietic acid		800	850*	330	380	1200	900*	560	660			
140	Cl_2-dehydroabietic acid												
137	epoxystearic acid												
138	dichlorostearic acid												
54	isophorone												
55	naphthalene												
1	acenaphthene												
77	acenaphthylene												
78	anthracene												
39	fluoranthene												
84	pyrene												
76	chrysene												
% Recovery	stearic acid D35												
	phenol D5												
	naphthalene D8												
	diamyl phthalate												

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

SEMIVOLATILE ORGANICS MILL NO. W

EPA NO.	Compound	Sample Number											
		St. Regis 100979	St. Regis 101179										
44	methylene chloride		5										
49	trichlorofluoromethane												
13	1,1-dichloroethane		2										
23	chloroform	37	20										
10	1,2-dichloroethane												
11	1,1,1-trichloroethane		8										
15	1,1,2,2-tetrachloroethane												
6	carbon tetrachloride												
48	dichlorobromomethane												
87	trichloroethylene												
51	dibromochloromethane												
4	benzene												
47	bromoform												
85	tetrachloroethylene	5	5										
86	toluene	1	2										
7	chlorobenzene												
38	ethylbenzene	3											
143	xylenes	4											

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

VOLATILE ORGANICS MILL NO. S

EPA NO.	Compound	Sample Number											
		S10-Blk	S10-8	S10-9	S10-10	S10-11	S10-12	S10-13					
70	diethyl phthalate												
68	di-n-butyl phthalate		7					18					
67	butyl benzyl phthalate												
66	bis(2-ethylhexyl) phthalate	5	6	5	5	**	8	6					
69	di-n-octyl phthalate												
65	phenol		3*	7	7	8	11	14					
24	2-chlorophenol												
31	2,4-dichorophenol												
21	2,4,6-trichlorophenol												
64	pentachlorophenol												
22	p-chloro-m-cresol												
59	2,4-dinitrophenol												
134	oleic acid		82	130	150	110*	140*	380					
135	linoleic acid		28	74	79	28	67	120					
136	linolenic acid												
133	pimaric acid		16	25	36	34	51	120					
132	isopimaric acid		8	47	67	51	82	55					
131	dehydroabietic acid		31	230	360	380	440	330					
130	abietic acid		57	200	300	160	190	240					

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

SEMIVOLATILE ORGANICS MILL NO.S

EPA NO.	Compound	Sample Number											
		S10-Blk	S10-8	S10-9	S10-10	S10-11	S10-12	S10-13					
141	trichloroguaiacol												
142	tetrachloroguaiacol												
139	1-Cl-dehydroabietic acid												
140	Cl_2-dehydroabietic acid												
137	epoxystearic acid												
138	dichlorostearic acid												
54	isophorone												
55	naphthalene												
1	acenaphthene												
77	acenaphthylene												
78	anthracene												
39	fluoranthene												
84	pyrene												
76	chrysene												
% Recovery	stearic acid D35												
	phenol D5												
	naphthalene D8												
	diamyl phthalate												

*Characteristic ion present at predicted retention time but confirmatory ion(s) missing.
**GC/MS data exhaustively re-examined, and this priority pollutant is definitely not present.

SEMIVOLATILE ORGANICS MILL NO. S

APPENDIX E

DATA MANAGEMENT

DATA MANAGEMENT

The raw wastewater samples were analyzed by both the E.C. Jordan Co. and Gulf South Research Institute except Wisconsin Tissue Mills. Wisconsin Tissue Mills were analyzed by the E.C. Jordan Co. only. Weighted average values were obtained for each day's data using the following procedure.

The sum of the concentration for each compound for each laboratory was obtained and an average summation value for that compound was obtained. Data obtained from one laboratory that did not have a corresponding data entry from the other laboratory was not used in the calculations of the individual summation values. For data entries not detected, a detection limit value of 5 ug/l was used.

A multiplier factor was obtained for each laboratory by dividing the average summation value by the summation value for each laboratory.

The factors were then applied to each laboratory's analytical data and a weighted average concentration value was obtained.

COMPOUND - 2,4,6-TRICHLOROPHENOL

Example	Lab[1]	Lab[2]
	62	58
	ND = 5	21
	83	--
	29	57
	50	ND = 5
	150	83
	120	--
	110	ND = 5
	Σ 406	229
	Average Σ 320	
Factors	0.782	1.386

$$\text{Weighted Average} = \frac{(\text{Conc.}_1 \times f_1) + (\text{Conc}_2 \times f_2)}{2}$$

where:

Conc_1	=	Concentration in ug/l obtained from laboratory 1
Conc_2	=	Concentration in ug/l obtained from laboratory 2
F_1	=	Factor calculated for laboratory 1
F_2	=	Factor calculated for laboratory 2

Tables 21, 22, 23 and 24 summarize the actual average values, corrective factors, and the normalized data.

TABLE 32. SUMMARY OF ACTUAL AND NORMALIZED DATA - RAW WASTEWATER

Pollutant	EPA No.	Bergstrom Paper Co. Correction Factor "f"	Bergstrom Paper Co. Normal	Bergstrom Paper Co. Actual	Wisconsin Tissue Mills Normal	Wisconsin Tissue Mills Actual	St. Regis Paper Co. Normal	St. Regis Paper Co. Actual
Volatiles								
1,1,1-trichloroethane	11	8.60	42	5	--	--	--	--
chloroform	23	1.76	4,200	2,400	460	261	19	11
dichlorobromomethane#	48	0.788	870	1,100	--	--	--	--
trichloroethylene#	87							
Semivolatiles								
2,4,6-trichlorophenol	21	1.389	59	42	--	--	--	--
2,4-dichlorophenol	31	1.446	20	14	--	--	--	--
naphthalene	55	0.862	260	300	--	--	--	--
bis-(2 ethylhexyl) phthalate	66	1.232	--	--	68	55	--	--
di-n-butyl phthalate	68	1.232	--	--	260	210	--	--
abietic	130	0.897	55	61	1,700	1,900	290	330
dehydroabietic	131	0.606	3,900	6,500	4,700	7,800	710	1,200
isopimaric	132	0.697	240	340	610	880	90	130
pimaric	133	1.079	59	55	220	200	60	56
oleic	134	1.218	830	680	480	400	140	120
linoleic	135	0.864	360	410	150	180	73	84
monochloro dehydroabietic	139	0.681	230	340	1,300	2,000	--	--
3,4,5-trichloroguaiacol	141	1.167	6	5	--	--	--	--
tetrachloroguaiacol	142	1.217	8	7	--	--	--	--
Others								
PCB-1254	107	1.00	9	9	--	--	*	*
PCB-1016	112	1.00	26	26	34	34	*	*

Notes
Compounds coelute.
-- Compound not found.
* Compound not analyzed for in this sample.
All results expressed as ug/l.

TABLE 33. SUMMARY OF ACTUAL AND NORMALIZED DATA AIR SAMPLES

Pollutant	EPA No.	Correction Factor "f"	Bergstrom Paper Co. Normal	Bergstrom Paper Co. Actual	Wisconsin Tissue Mills Normal	Wisconsin Tissue Mills Actual	St. Regis Paper Co. Normal	St. Regis Paper Co. Actual
Volatiles								
1,1,1-trichloroethane	11	8.60	1.3/0.9	0.15/0.1	--	--	--	--
chloroform	23	1.76	4.4/3.6	2.5/2.0	4/3	2/1	0.4	0.2
dichlorobromomethane#	48	0.788	0.2/1.3	0.25/1.6	--	--	--	--
trichloroethylene#	87							
Semivolatiles								
2,4,6-trichlorophenol	21	1.389	--	--	--	--	--	--
2,4-dichlorophenol	31	1.446	--	--	--	--	--	--
naphthalene	55	0.862	--	--	--	--	--	--
bis-(2 ethylhexyl) phthalate	66	1.232	--	--	5/5	4/4	--	--
di-n-butyl phthalate	68	1.232	--	--	5/5	4/4	--	--
abietic acid	130	0.897	--	--	4/4	5/5	4	5
dehydroabietic acid	131	0.606	2/7	3/12	15/6	25/10	11	18
isopimaric acid	132	0.627	--	--	4/5	6/7	5	7
pimaric acid	133	1.079	--	--	7/4	7/4	6	6
oleic acid	134	1.218	--	--	5/6	4/5	6	5
linoleic acid	135	0.864	--	--	4/4	5/5	4	5
monochloro dehydroabietic acid	139	0.681	--	--	4/4	6/6	--	--
trichloroguaiacol	141	1.167	11/6	9.5	--	--	--	--
tetrachloroguaiacol	142	1.217	--	--	--	--	--	--
Others								
PCB-1254	107	1.00	*	*	*	*	*	*
PCB-1016	112	1.00	*	*	*	*	*	*

Notes
- # Compounds coelute.
- -- Compound not found.
- * Compound not analyzed for in this sample.
- / Aeration tank No. 1/Aeration tank No. 2

All results expressed as ug/6 liters.

TABLE 34. SUMMARY OF ACTUAL AND NORMALIZED DATA - DEWATERED SLUDGE

Pollutant	EPA No.	Correction Factor "f"	Bergstrom Paper Co. Normal	Bergstrom Paper Co. Actual	Wisconsin Tissue Mills Normal	Wisconsin Tissue Mills Actual	St. Regis Paper Co. Normal	St. Regis Paper Co. Actual
Volatiles								
1,1,1-trichloroethane	11	8.60	*	*	*	*	*	*
chloroform	23	1.76	*	8	*	*	*	*
dichlorobromomethane#	48	0.788	*	*	*	*	*	*
trichloroethylene#	87							
Semivolatiles								
2,4,6-trichlorophenol	21	1.389	140	100	--	--	--	--
2,4-dichlorophenol	31	1.446	150	100	--	--	--	--
naphthalene	55	0.862	430	500	--	--	--	--
bis-(2 ethylhexyl) phthalate	66	1.232	--	--	16,000	13,000	--	--
di-n-butyl phthalate	68	1.232	--	--	460	370	--	--
abietic acid	130	0.897	4,050	4,500	1,800	2,040	8,500	9,500
dehydroabietic acid	131	0.606	2,000	3,400	300	500	15,000	25,000
isopimaric acid	132	0.697	4,200	6,100	2,400	3,400	6,400	9,200
pimaric acid	133	1.079	2,200	2,000	540	500	540	500
oleic acid	134	1.218	2,300	1,900	1,300	1,100	1,600	1,300
linoleic acid	135	0.864	400	500	470	500	430	500
monochloro dehydroabietic acid	139	0.681	1,100	1,700	5,700	8,400	--	--
trichloroguaiacol	141	1.167	120	100	--	--	--	--
tetrachloroguaiacol	142	1.217	120	100	--	--	--	--
Others								
PCB-1254	107	1.00	650	650	--	--	*	*
PCB-1016	112	1.00	520	520	540	540	*	*

Notes
Compounds coelute.
-- Compound not found.
* Compound not analyzed for in this sample.
All results expressed as ug/kilogram of dewatered sludge.

TABLE 35. SUMMARY OF ACTUAL AND NORMALIZED DATA - FINAL EFFLUENT

Pollutant Name	EPA No.	Bergstrom Paper Co. Correction Factor "f"	Bergstrom Paper Co. Normal	Bergstrom Paper Co. Actual	Wisconsin Tissue Mills Normal	Wisconsin Tissue Mills Actual	St. Regis Paper Co. Normal	St. Regis Paper Co. Actual
Volatiles								
1,1,1-trichloroethane	11	8.60	12	1	--	--	--	--
chloroform	23	1.76	66	38	43	24	10	6
dichlorobromomethane#	48	0.788	9	11	--	--	--	--
trichloroethylene#	87							
Semivolatiles								
2,4,6-trichlorophenol	21	1.389	81	58	--	--	--	--
2,4-dichlorophenol	31	1.446	18	12	--	--	--	--
naphthalene	55	0.862	10	12	--	--	--	--
bis-(2 ethylhexyl) phthalate	66	1.232	6	5	5	4	--	--
di-n-butyl phthalate	68	1.232	6	5	5	4	--	--
abietic acid	130	0.887	6	7	19	21	12	13
dehydroabietic acid	131	0.606	35	58	38	63	5	8
isopimaric acid	132	0.697	6	9	6	9	3	4
pimaric acid	133	1.079	5	4	5	4	33	31
oleic acid	134	1.218	21	17	40	33	79	65
linoleic acid	135	0.864	4	5	4	5	35	41
monochloro dehydroabietic acid	139	0.681	57	84	140	200	--	--
trichloroguaiacol	141	1.167	37	32	--	--	--	--
tetrachloroguaiacol	142	1.217	28	23	--	--	--	--
Others								
PCB-1254	107	1.00	0.1	--	--	--	*	*
PCB-1016	112	1.00	0.1	--	0.05	0.05	*	*

Notes
Compound co-elutes.
-- Compound not found.
* Compound not analyzed for in this sample.
All results expressed as ug/l.

GLOSSARY OF PULP AND PAPERMAKING TERMS

Activated sludge process - Process of using biologically active sewage sludge to hasten breakdown of organic matter in raw sewage during secondary waste treatment.

Aeration - Process of being supplied or impregnated with air. Aeration is used in wastewater treatment to foster biological and chemical purification.

Air dry (AD) ton - Measurement of production including a moisture content of 10 percent by weight.

Bale - Standard bale of waste paper is 72 in. long, 32 in. wide, and 28 in. deep, with a content of about 37 ft^3. It weighs 900 to 1,000 lb. The size and weight may vary with the grade of paper. A bale of pulp varies in weight from 400 to 500 lb and is approximately 30x30x13 in. in size. A bale of rags varies in weight from 700 to 1,300 lb and will vary in dimensions according to the press used. Typical dimensions are 26x30x72 in., 26x42x72 in., or 26x52x54 in. A bale of bags weighs 61 to 62 lb.

Bark - Protective covering of a tree.

Barker - Piece of equipment designed to remove the bark from a log.

Barking - Operation of removing bark from pulpwood prior to processing, carried out by means of a knife, drum, mechanical abrasion, hydraulic barker, or by chemical means.

Biological oxidation - Process by which bacterial and other microorganisms feed on complex organic materials and decompose them. Self-purification of waterways and activated sludge, and trickling filter wastewater treatment processes depend on this principle. The process is also called biochemical oxidation.

Bleaching - Brightening and delignification of pulp by the addition of oxidizing chemicals (e.g., chlorine), or reducing chemicals (e.g., sodium hypochlorite).

Biochemical oxygen demand (BOD5) - Quantity of dissolved oxygen utilized in the biochemical oxidation of organic matter in a specified time (5 days) and at a specified temperature. It is not related to the oxygen requirements in chemical combustion, being determined entirely by the availability of the material as a biological load and by the amount of oxygen utilized by the microorganisms during oxidation.

Bone dry - See oven dry.

Brightness - As commonly used in the paper industry, the reflectivity of a sheet of pulp, paper or paperboard for specified light measured under standardized conditions.

Broke - Partly or completely manufactured paper that does not leave the machine room as salable paper or paperboard; also paper damaged in finishing operations such as rewinding, cutting and trimming.

"C" stage - Abbreviation for the chlorination stage of bleaching.

Calcium hypochlorite - Chemical commonly used in the paper industry for bleaching pulp, and in water treatment as a germicide.

Capacity - Production of a unit, usually in tons per day.

Chemical wood pulp - Pulp obtained by digestion of wood with solutions of various chemicals. The principal chemical processes are the sulfite, sulfate (kraft), and soda processes.

Chips - Small pieces of wood used to make pulp.

Chipper - Machine consisting essentially of a revolving disk equipped with heavy radially-arranged knives, which cuts pulpwood and saw mill waste into slices or chips, diagonal to the grain.

Clay - In general, a natural, earthy, fine-grained material that develops plasticity when wet, but hard when baked or fired. Used as filler and coating paper sheets.

Cleaner - Device creating a cyclone effect to remove dirt and other rejects from pulp using the differences in density to aid in separation.

Chlorine dioxide - Chemical (ClO_2) used in pulp bleaching as a water solution, usually in one or more of the latter stages of a multistage sequence. It is prepared by a variety of processes at the plant site usually from sodium chlorate, acid, and a reducing agent.

Clarifier - In wastewater treatment, a settling tank which mechanically removes settleable solids from wastewater.

Coated - Term applied to paper and paperboard, the surface of which has been treated with clay or some other pigment and adhesive mixture or other suitable material, to improve the finish for printing quality, color, smoothness, opacity, or other surface properties. The term is also applied to lacquered and varnished papers.

Chemical oxygen demand (COD) - Amount of oxygen required to meet chemical requirements, as well as BOD.

Color - Refers to standard APHA Platinum Cobalt Test, using standards for color intensity of water samples. Commonly, standards are prepared at various concentrations which later may be referenced as units of color, derived from flow and concentration standard.

Color unit - Measure of color concentration in water, using NCASI methods.

Converting - Any operation in which paper is made into a product, not necessarily the final product.

Cooking - Heating of wood, water, and chemicals under pressure in a closed vessel to a temperature sufficient to separate the fibrous portion of wood by dissolving lignin and other nonfibrous constituents.

Cord - Term used in the measurement of pulpwood. The usual definition is a pile 8 ft long, 4 ft wide, and 4 ft high, containing 128 ft^3 (see also Cunit).

Cotton linters - Short fibers surrounding the cotton seed.

Cylinder machine - One of the principal types of papermaking machines, characterized by the use of wire-covered cylinders or molds on which a web is formed. These cylinders are partially immersed and rotated in vats containing a dilute stock suspension. The pulp fibers are formed into a sheet on the mold as the water drains through and passes out at the ends of the cylinders. The wet sheet is couched off the cylinder onto a felt, which is held against the cylinder by a couch roll. A cylinder machine may consist of one or several cylinders, each supplied with the same or different kinds of stock. In the case of a multicylinder machine, the webs are successively couched one upon the other before entering the press section. This permits wide variation in thickness or weight of the finished sheet, as well as a variation in the kind of stock used for the different layers of the sheet.

"D" stage - Abbreviation for the chlorine dioxide stage.

"DC" stage - Stage where chlorine dioxide and chlorine are applied sequentially.

Decker - Piece of equipment commonly used to thicken pulp. It consists of a wire covered drum in a pulp vat. A vacuum is applied to the center of the drum, commonly by a barometric leg, to pull water out of the stock slurry.

Deinking - Operation of reclaiming fiber from waste paper by removing ink, coloring materials, and fillers.

Density - Weight per unit volume. Density should not be confused with porosity.

Diffusion washing - Washing pulps with an open ended vessel by diffusing or passing the wash media through the pulp mass.

Digester - Vessel used to treat pulpwood, straw, rags or other such cellulosic materials with chemicals to produce pulp. The vessel is usually built to withstand elevated pressures and is made of materials designed to resist the chemical action of the cooking process. It may be cylindrical or spherical in shape. It may be designed for batch operation with discharge at the conclusion of a final cycle by release of internal pressure through a valved port, or by dumping. It may also be built for continuous operation by providing a means to transporting the raw material and cooking chemical from a fixed point at the charging end of the digester to the discharging end.

Dirt - Foreign matter embodied in a sheet of paper, paperboard, or pulp which has a marked contrasting color to the rest of the material when viewed by reflected or transmitted light. Generally determined by reference to a standard dirt chart.

Disk refiner - Motor-driven refiner whose working elements consist of one or more matched pairs of disks having a pattern of ribs machined into their faces, and arranged so that one disk of the pair is rotated. The other disk is usually stationary, but may be driven in the opposite direction of rotation. Precision controls are provided for adjusting the clearance between the disk faces and applying pressure between them. The disks are enclosed in a case arranged so that a suspension of paper stock can be pumped in and caused to flow radially from the center out, or vice versa, between the rapidly moving ribbed surfaces of the disks, thus resulting in refining. The refining action on the fiber material is dependent upon such variables as pressure between the two disks, the exact pattern of ribs on the disks, speed of rotation, and consistency of the pulp suspension.

Dissolved oxygen - Amount of oxygen, expressed in parts per million, dissolved in water.

Dissolved solids - Total amount of dissolved material, organic and inorganic, contained in water or wastes. Excessive dissolved solids make water unpalatable for drinking and unsuitable for industrial use.

Dregs - Inert rejects from the green liquor clarifier of a pulp mill.

"E" stage - Abbreviation for the caustic extraction stage of the bleaching sequence.

Extended aeration - Modification of the activated sludge process that employs aeration periods of 18 hours or more.

Fiber - Cellulosic portion of the tree used to make pulp, paper, and paperboard.

Filler - 1) A material, generally nonfibrous, added to the fiber furnish of paper, 2) In paperboard, the inner ply or plies of a multiple layer product.

Fines - Very short pulp fibers or fiber fragments and ray cells. They are sometimes referred to as flour or wood flour.

Finishing - Various operations in the manufacture and packaging of paper performed after it leaves the papermachine. Finishing operations include supercalendering, plating, slitting, rewinding, sheeting, trimming, sorting, counting and packaging. Ruling, punching, pasting, folding and embossing are also sometimes considered as finishing operations.

Flume - Sloped trough used to transfer pulpwood from one point to another using water flow.

Grade - The type of pulp or paper product manufactured.

Grinder - Machine for producing mechanical wood pulp or groundwood. It is essentially a rotating pulpstone against which logs are pressed and reduced to pulp.

Groundwood papers - General term applied to a variety of papers, other than standard newsprint, made with substantial proportions of mechanical wood pulp together with chemical wood pulps, and used mainly for printing and converting purposes.

"H" stage - Abbreviation for the hypochlorite stage of bleaching.

Hardwood - Term applied to wood obtained from trees of the angio-sperm class. The hardwoods are obtained from dicotyledonous trees such as birch, gum, maple, oak and poplar. The leaves are broad except in rare instances and are usually deciduous in the temperate zones. The seeds are enclosed in a fruit which is either fleshy or dry at maturity. Hardwoods are also designated as porous woods.

Kappa numbers - Permanganate number of a pulp measured under controlled conditions and corrected to be the equivalent of 50 percent consumption of the permanganate solution in contact with the specimen. It gives the degree of delignification of pulp through a wider range than does the older permanganate number test.

Knots - Imperfections in paper or lumps in paper stock resulting from: 1) incompletely defibered textile materials; the term applies especially to rag paper manufacture; 2) small undefibered clusters of wood pulp; and 3) the basal portion of a branch or limb which has become incorporated in the body of the tree.

Kraft - Term describing of the (alkaline) sulfate pulping process, the resulting pulp, and paper or paperboard.

Lignin - Non-degradable organic compound of wood which is removed during pulping.

Linerboard - Paperboard made on a fourdrinier or cylinder machine and used as the facing material in the production of corrugated and solid fiber shipping containers. Linerboard is usually classified according to furnish and method of wet formation, as for example fourdrinier kraft linerboard, cylinder kraft linerboard, jute linerboard.

Mechanical pulp - Pulp produced by physical means without the use of chemicals or heat, often referred to as groundwood.

Molded pulp products - Contoured products such as egg packaging items, food trays, plates, bottle protectors, etc., made by depositing fibers from a pulp slurry onto a forming mold of the contour and shape desired in the product. To achieve fiber deposition, either pressure or vacuum may be applied to the pulp slurry.

NCASI - National Council for Air and Stream Improvement. An organization of the pulp and paper industry concerning itself with environmental affairs pertaining to the industry.

Newsprint - Paper, made largely from groundwood pulp with a small percentage of chemical pulp added for strength, used chiefly in the printing of newspapers.

Neutral sulfite semi-chemical pulp (NSSC) - Usually made from hardwoods, although softwoods which are low in resin content can also be used. The active cooking agent is sodium sulfite with sufficient sodium carbonate added to ensure that the cooking liquor remains slightly alkaline until blown. When pulping for bleachable grades, the cooking is carried out to a yield in the range of 62 to 68 percent. For unbleached grades, yields as high as 75 to 80 percent may be attained. Higher yield pulps, which account for the major NSSC production, are notable for their stiffness and have wide application in corrugating medium.

Nutrients - Elements, or compounds, essential as raw materials for organism growth and development (as in activated sludge process).

Oven dry - Containing no moisture. A pulp or paper which has been dried to a constant weight at a temperature of 100 to 105°C (212 to 221°F).

Oxidation pond - Man-made pond in which organic wastes are reduced by bacterial action. Often oxygen is bubbled through the pond to speed the process.

Paper - 1) General term: Name for all kinds of matted or felted sheets of fiber (usually vegetable, but sometimes mineral, animal or synthetic) formed on a fine screen from a water suspension. Paper derives its name from papyrus, a sheet made by pasting together thin sections of an Egyptian reed (Cyperus papyrus) and used in ancient times as a writing material. 2) Specific term: One of the two broad subdivisions of paper (general term), the other being paperboard. The distinction between paper and paperboard is not sharp but, generally speaking, paper is lighter in basis weight, thinner, and more flexible than paperboard. Its largest uses are for printing, writing, wrapping and sanitary purposes, although it is also employed for a very wide variety of other uses.

Paperboard - One of the two broad subdivisions of paper products. Paperboard is heavier in basis weight, thicker, and more rigid than paper. In general, all sheets 12 points (0.012 in.) or more in thickness are classi-

fied as paperboard. There are a number of exceptions based upon traditional nomenclature. For example, blotting paper, felts, and drawing paper in excess of 12 points are classified as paper, while corrugating medium, chipboard, and linerboard less than 12 points are classified as paperboard. Paperboard is made from a wide variety of furnishes on a number of types of machines, principally cylinder and fourdrinier. The broad classes are: 1) container board, which is used for corrugated cartons; 2) boxboard, which is further divided into: a) folding boxboard, b) special food board, and c) setup boxboard; and 3) all other special types such as automobile board, building board, etc.

Peroxide - Chemical used in bleaching of wood pulps, usually groundwood pulps.

Pulp - Cellulosic fibers after conversion from wood chips.

Pulper - Mechanical device resembling a large-scale kitchen blender used to separate fiber bundles in the presence of water prior to papermaking.

Pulping - The operation of reducing a cellulosic raw material (e.g., pulpwood, rags, straw, reclaimed paper, etc.) into a pulp suitable for papermaking.

Pulpwood - Those woods suitable for the manufacture of chemical or mechanical wood pulp. The wood may be in the form of logs as they come from the forest or cut into shorter lengths suitable for the chipper or the grinder.

Refiner - Machine used to rub, macerate, bruise, and cut fibrous material, usually cellulose, in water suspension to convert the raw fiber into a form suitable for formation into a web of desired characteristics on a papermachine. The many types of refiners differ in size and design features but most can be classified as either jordans or disk refiners. Beaters are not usually referred to as refiners, although in a broad sense they serve a similar function. Refiners may be used in various combinations of types and numbers of units depending on the type of stock to be treated and the capacity required (see deflaker, disk refiner, jordan).

Refining - General term applied to several operations, all involving the mechanical treatment of pulp in a water suspension to develop the necessary papermaking properties of the fibers and to cut the fibers to the desired length (see refiner).

Rejects - Material unsuitable for pulp or papermaking, separated in the manufacturing process.

Roundwood - Logs as received in the woodyard. The logs can be any length and usually have not been debarked.

Saveall - Mechanical device used to recover papermaking fibers and other suspended solids from a wastewater or process stream.

Screening - 1) Passing chips over screens to remove sawdust, slivers and oversize chips. 2) Passing pulp or paper stock through a screen to reject coarse fibers, slivers, shives, knots, etc.

Sheet - 1) Single piece of pulp, paper or paperboard. 2) Continuous web of paper as it is being manufactured. 3) General term for a paper or paperboard in any form and in any quantity which, when used with appropriate modifying words, indicates with varying degrees of specificity, attributes of the product such as quality, class, use, grade, or physical properties (e.g., bright sheet, kraft sheet, folding boxboard sheet). 4) Cutting paper or paperboard into sheets of desired size from roll or web.

Sizing - 1) Relates to a property of paper resulting from an alteration of fiber surface characteristics. In terms of internal sizing, it is a measure of the resistance to the penetration of water and various liquids. In terms of surface sizing, it relates to the increase of such properties as water resistance, abrasion resistance, abrasiveness, creasibility, finish, smoothness, surface bonding strength, printability, and the decrease of porosity and surface fuzz. 2) Addition of materials to a papermaking furnish or the application of materials to the surface of paper and paperboard to provide resistance to liquid penetration and, in the case of surface sizing, to affect one or more of the properties listed in 1).

Sludge - Semi-fluid mixture of fine solid particles with a liquid. May contain fibrous and filler materials, and/or biological solids.

Softwood - Softwoods, or coniferous woods, come from coniferous trees such as pines, spruces, and hemlocks.

Stock - 1) Pulp that has been beaten and refined, treated with sizing, color and filler. After dilution, it is ready to be formed into a sheet of paper. 2) Wet pulp of any type at any stage in the manufacturing process. 3) Paper in inventory or in storage. 4) Paper or other material to be printed, especially the paper for a particular piece of work. 5) Describes a paper suitable for the indicated use, such as coating raw stock, milk carton stock, tag stock, towel stock, etc.

Stock preparation - Term for the several operations occurring between pulping (or bleaching) and formation of the web on a papermachine. It may include repulping, beating, refining and cleaning.

Suspended solids (TSS) - Small particles of solid pollutants in sewage that contribute to turbidity and that resist separation by conventional means. The examination of suspended solids and the BOD_5 test constitute the two main determinations for water quality performed at mills and wastewater treatment facilities.

Unbleached - Paper or pulp which has not been treated with bleaching agents.

Virgin wood pulp - Pulp made from wood, as contrasted to waste paper sources of fiber.

Waste paper - General term used to specify various recognized grades such as No. 1 news, new kraft corrugated cuttings, old corrugated containers, manila tabulating cards, coated soft white shavings, etc. It is used as a principal ingredient in the manufacture of certain types of paperboard, particularly boxboard made on cylinder machines where the lower grades may go into filler stock, and the higher grades into one or both liners. Selected grades are also used in the manufacture of various papers.

Wet broke - Undried waste stock taken off the papermachine at the presses or before entering the driers (see also broke).

Wet end - Portion of the papermachine between the headbox and the drier section (see fourdrinier machine).

Whitewater - General term for all papermill waters which have been separated from the stock or pulp suspension, either on the papermachine or accessory equipment, such as thickeners, washers, and savealls, and also from pulp grinders. It carries a certain amount of fiber and may contain varying amounts of fillers, dyestuffs, etc.

Woodroom - Area of a pulp mill that handles the barking, washing, and chipping or grinding of logs. Purchased chips are also processed through the woodroom.

Woodyard - Area of a mill where roundwood is received and stored prior to transport to the woodroom.